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PROBLEMS OF SOIL SCIENTISTS AND AGROCHEMISTS IN CONNECTION WITH THE PROGRAM OF BUILDING COMMUNISM

The 22nd Congress of the Soviet Communist Party adopted an imposing program for the construction of a Communist Society. The Party and the whole Soviet people are faced with the real task of achieving an immense rise in production in the coming twenty years, and creating an abundance of material wealth so as to proceed at the end of the twenty year period to Communist principals of the distribution of social benefits. Our society is also faced with immense problems in the education of the new man — the builder of Communism.

The importance of science has never been so great as in the building period of socialism and communism. Under communism science will become the most important force in production, "the decisive factor in the great rise in the productive forces of society".[1]

The sections in the program of the Soviet Communist Party dealing with the development of science and the section on the growth of agriculture define the problems facing soil scientists and agrochemists with great clarity and profundity. The most important of these problems is developed of the scientific principals for rational use of "the main means of agricultural production" (in the expression of Karl Marx) — the land.

The creation of an abundance of agricultural products calls primarily for a fundamental increase in the fertility of soils and the yield of agricultural crops based on the scientific distribution of agriculture by natural and economic zones and regions; more profound specialization; improvement in the level of agriculture; and introduction of scientifically evolved systems of agriculture that correspond to soil and climatic conditions and the development of livestock industry. This task laid down in the program is a guide for the daily activity of the agronomists, soil scientists, and agrochemists of the Soviet Union. The vast expanses of our Mother Land, with its extremely diverse conditions, call for the introduction of differentiated farming techniques and the rational selection of crops and the structure of sown areas. The development of differentiated systems of agriculture should be based on the establishment of soil and climatic region. This work, which has been carried out in recent years for the territory of the Soviet Union by a group of Soviet soil scientists has been possible mainly as a result of many years of extensive work on soil cartography. The development and introduction of scientific agricultural systems calls for a great effort from the soil scientists of the USSR to draw profound theoretical conclusions from all the accumulated material on the qualitative features of the land resources, on the study of soil processes, water, air, heat, gas and nutrient regimes, etc., on the agrochemical, agrophysical and meliorative description of the country's soil, and on the mapping of soil erosion.

In addition to more profound soil studies in areas that have long been utilized, extensive soil-geographical and soil-meliorative work must be developed in the next twenty years in Western and Eastern Siberia and in the Far East. The development of new industrial centers in these districts has already demanded the setting up of agricultural supply bases and this requires comprehensive study of the natural resources of Siberia and the Far East and the discovery of new areas of virgin land suitable for agricultural use.

Existing soil classification and taxonomy is based primarily on a study of the static properties of soils and the factors of soil formation. Much work must be done to perfect and extend the taxonomy and classification of natural soils and to develop a classification of cultivated soils, taking into consideration the extensive material for large scale soil mapping in kolkhozes and sovkhozes, research on the soil geography of little studied districts in the Soviet Union and abroad, and the results of work on soil processes at research stations.

The task set out in the Party program of increasing the use of chemicals in agriculture and stepping up the satisfaction of agricultural demands for industrial and locally produced mineral and organic fertilizers requires great work from agrochemists to establish the most effective quotas, times, and rates for the use of fertilizers with different crops on different soils. Agrochemists must cooperate closely with entomologists, plant physiologists, microbiologists, and phytopathologists in a penetrating and comprehensive study of the effect of the chemicals used in weed and pest control on plants, micro-organisms, and soil fertility.

Man's influence on nature increases year by year in our country. The builders of communism are laying down canals and irrigating deserts, draining vast areas of marshy land and bog, and altering the nature of natural vegetation, which are also affecting soil processes. Soil scientists must make a far reaching study of the effects of soil improvement and agricultural practices on the soil so as to evolve methods for the control of soil-forming processes. This is one of the most important theoretical and practical tasks of soil science during the building of communism.

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[1] Draft program of the CPSU, "Kommunist", No. 11, page 72, 1961.

In the new stage being entered upon by soil science, it is essential to organize an extensive coverage of research on soil processes at research stations. There must be an extended program at experiment stations, in the leading kolkhozes and sovkhozes, and at specially organized units in all the natural zones and provinces. This research will yield materials that will assist in the development of methods for creating highly fertile soil throughout our nation.

The extensive plan for irrigation work envisaged in the Party Program for the irrigation and water supply of 28 million hectares of new lands in arid regions and the improvement of excessively wet soils in the non-chernozem zone requires the active participation of soil scientists. We need a description of the new districts from the point of view of soil improvement, a study of the effects of the new methods of soil improvement on the soil, on the physicochemical properties of soils and their fertility, on the water and salt regime of soil, and on the ground water regime. In the next few years irrigation will be extended from Central Asia and Transcaucasia (the old irrigated districts) to new districts of the Volga region, the south of the Ukraine, the Northern Crimea, and Ciscaucasia. These new districts are as yet little studied from the point of view of soil improvement. The ambitious plan for turning the waters of the northern rivers into the Volga requires a painstaking soil and hydrological description of the basins of these rivers, since the creation of vast reservoirs in the north may inundate agricultural lands and give rise to marshes.

Particular mention should be made of the reclamation of millions of hectares of bogs and water-logged lands. Reclamation is highly developed in our country. Highly efficient machines for reclamation work have begun to reach the organizations concerned with this work in agriculture in the last few years. There has been much reclamation of bogs and water-logged soils and construction of open drainage (the most effective drainage system) in the Belorussian, Lithuanian, Latvian and Estonian Republics, and in the Leningrad and Moscow regions. This work has shown that there is a rapid return for expenditure on the reclamation of bogs and water-logged soils and that such soils can produce persistently high crops of vegetables and forage even in the first years of use.

Studies of soil processes in the recent reclamation and utilization of bogs in different natural regions have shown that the existing methods should not be rigidly applied. Identical methods should not be used under different soil and climatic conditions. The development of differentiated methods for the reclamation and utilization of bogs and water-logged soils must be based on a complete study of the processes involved in the carrying out of these measures in different natural regions. If insufficient allowance is made for natural conditions and if irrational methods are employed, the fertility of the soils will decline and may even be lost and the yield of the crops grown on them will be reduced.

The section of the Party Program dealing with the development of the kolkhozes mentioned the need to create conditions in which the economic opportunities of collective farms in uneven, natural and economic conditions would be the same. In addition to developing methods for cultivation and for greatly improving the fertility of soil, soil scientists, and agrochemists must join forces with economists in the next few years to improve the site quality of soil, or, more accurately, of land. This work, which is intimately connected with the large-scale mapping of kolkhoz and sovkhoz land should be completed in the next few years. The application of a site quality index will enable us to fulfill the demand in the Party Program that the principal of equal pay for equal work should be applied throughout the collective farm system as long as the socialist principal of payment for work remains in force.

Many of the problems enumerated can only be successfully solved if everything possible is done to improve field and laboratory methods for soil research using achievements in physics, chemistry and other special disciplines, and supplying soil and agrochemical institutes and experiment stations with improved instruments and apparatus. One of the urgent tasks facing soil science and agrochemistry is stubborn and persistent development of new methods and the rapid introduction of the best of these methods into general use.

A correct solution of the problem of training soil scientists and agrochemists will have immense bearing both on the theory and practice of soil science and agrochemistry and on the introduction of their achievements into agriculture. The difficult situation in the training of replacements has already been discussed repeatedly at meetings of soil scientists and agrochemists and in the press. In view of the great tasks that face us this problem must be rapidly solved.

The task that the Party sets all the scientists of our country is "... to strengthen the leading positions that Soviet science has won in the most important branches of knowledge and to occupy the leading position in all the main trends in world science." Soviet soil science has always occupied a leading position in the world since the time of V. V. Dokuchayev. If its authority is to be further increased we must develop the theory of soil science more profoundly, solve a number of philosophical problems concerning our science, introduce more generally a wide approach to the solution of problems connected with soil genesis and fertility, and link our research more closely to the sciences of the agricultural, physical, and chemical cycles.

In the last ten years Soviet soil scientists have given important assistance in the development of soil science and the carrying out of soil research to the people's democracies and to the independent countries of Asia and Africa that have thrown off the colonial yoke. Much work has been done in the People's Republic of China, Bulgaria, Romania, Burma, Vietnam, and other countries. We must assist the independent countries of the African continent. The contacts between Soviet soil scientists and those of all the countries in the world will be extended and strengthened in the next few years. It is already necessary to begin preparation for the 8th Congress of Soil Science to be held in the Romanian People's Republic in 1964.

Inspired by the decisions of the 22nd Congress, soil scientists and agrochemists will combine with the whole of our people in using all their knowledge and strength to create rapidly an abundance of material benefits and to bring closer the communist era.

REGIONAL SUBDIVISION OF RECLAIMED WATER-LOGGED SOILS IN NONCHERNOZEM ZONE AND SOME PROBLEMS OF THEIR STUDY

F. R. ZAYDEL'MAN, Rosgiprovodkhoz

Increased agricultural production in the non-chernozem zone is intimately associated with the improvement, reclamation, and use of water-logged soils.

The improvement and agricultural use of peat soils has been studied in detail by the work of Soviet and foreign (mainly German, Polish, and Scandinavian) soil scientists and reclamation experts, but little has yet been done on many aspects concerning mineral water-logged soils. Approximately 70% of the total land resources available for drainage in the non-chernozem zone consists of mineral water-logged soils.

Various aspects of the study of water-logged soils in the non-chernozem zone related to the planning of reclamation, construction of drainage systems, and agricultural use will be considered in this paper.

An anaerobic period of varying duration is a feature of all soils in the zone, but the term water-logged is applied to mineral soils in which the anaerobic period is so prolonged that crop growth and development is difficult or impossible.

Gleying of the horizons in the soil profile, accumulation of raw humus, and peat formation in the accumulative horizon are all features of water-logged soils. At the same time aerobic conditions are of sufficient duration in water-logged soils to prevent the accumulation of peat.

Soils which are temporarily excessively moist, in which the duration of anaerobic conditions do not adversely affect the development of crops but on which conditions are unfavorable for the use of machines and implements, may be provisionally grouped with water-logged soils.

Regional subdivision is an important aspect of reclamation studies. For purposes of drainage, a reclamation district is a group of soils in which water-logging is due to the same causes and in which the methods for the elimination are the same. The soils within such a group must be further differentiated by the degree of water-logging and fertility.

Regional subdivision of water-logged soils for reclamation should therefore be based on the following four principles:

1) Cause of water-logging. The method of drainage (lowering of the ground water level, improvement of runoff, destruction of water-impermeable layers, etc.) is decided when the cause of water-logging has been established;

2) Degree of water-logging. The need to drain separate areas of the land mass for different agricultural use is established from information on the degree of water-logging;

3) Fertility of water-logged soils (before and after draining). Information on the fertility of the soils under consideration is used to establish the desirability of drainage, to plan the sequence of the work, and to decide on the cultivation and farming practices to be used in bringing the drained area under cultivation;

4) Uniformity of reclamation methods and prevention of secondary water-logging within the district. In this connection, changes in the soil after drainage and a description of the structural properties of the soil layer should be features of regional subdivisions.

These basic principals have been used to produce the summary of present views on methods for the improvement and agricultural use of water-logged soils in the non-chernozem zone given in Table 1. It emerges from this outline that water-logging in the non-chernozem zone is due to the trapping of ground (and hydrostatic) waters and the prolonged stagnation of surface water (atmospheric water, downhill drainage, and fluvial) or to the development of a vegetation associated with a progressive, unfavorable condition of mineral nutrition (biogenic water-logging). Water-logging is not infrequently due to degradation of the agriculturally valuable properties of soils by human activity (anthropogenic water-logging) or to the formation of water-impermeable layers during soil formation (pedogenic water-logging).

It is convenient to distinguish seven groups of water-logged soils for drainage purposes in the non-chernozem zone (see the Table).

The causes of water-logging are a guiding factor in the regional subdivision of soils for reclamation purposes, because they determine the drainage method and because soil genesis and fertility are intimately associated with them.

One can distinguish soils of two basic geomorphological elements (floodplain and watershed [non-floodplain] areas) in the non-chernozem zone. Water-logging of soils in watershed areas may be produced by atmospheric and ground waters, downhill drainage, biogenic, and pedogenic and anthropogenic factors. Atmospheric, biogenic, pedogenic, and anthropogenic water-logging, being associated with deterioration of soil structure, are not normally found in floodplain areas and downhill drainage is only of minor importance.

In watershed areas soils become water-logged by surface waters under a leaching regime. This circumstance, plus the combination of bog and podzolic soil-forming processes and the acid nature of the majority of the soil-forming parent materials, provides the main reason for the low general fertility of water-logged soils in watershed areas. Drainage alone has little or no effect on their fertility and crop yields that justify the expenditure on improvement can only be obtained by intensive farming involving the application of large amounts of organic and mineral fertilizers.

The same considerations apply to a large extent to watershed soils water-logged by soft and iron-containing ground waters. Excluded in this relationship are soils water-logged by hard waters. When drained they give a considerable economic return for a comparatively low expenditure.

Soils water-logged by percolating water from water courses or by percolating water and ground waters in the central and along the terraced of a floodplain area are usually extremely fertile after drainage.

The outline gives information on grain yields (especially spring wheat) on drained land with and without the use of fertilizers. This information can be used with some degree of approximation to forecast the fertility of water-logged mineral soils after draining. It emerges from Table 1 that the agricultural success of measures to improve mineralized water-logged soils in the non-chernozem zone is largely determined by the level of farming technique and especially the fertilizer plan.

This information, which is derived from the author's field observations and from the literature, can be used to develop a site quality index for water-logged soils.

Determination of the causes of water-logging is a crucial aspect of the study of water-logged soils, but methods to develop research procedure is lacking. Shrag (9) has made the most promising suggestions. The causes of water-logging (and therefore the classification of the soils in the regional subdivisions) are established from a study of the various landscape elements — vegetation, soils, hydrogeological, and geomorphological structure. For practical purposes, however, it is often sufficient to study only two or three attributes (e. g. vegetation, soil genesis, and texture). Thus, the water-logging of soddy granular soils is usually due to percolation waters along the water courses. The existence of bog marl and kunkur in the soil profile is an indication of water-logging by hard ground waters.

Coarse textured sod-podzolic soils become water-logged when the existence of a deep ground water table is associated with the presence of thin water-impermeable ortsand layers that develop in the process of podzol-formation. Conversely the pressure of thick ortstein patches in the profile of soddy-sandy soils and sandy loams in the aëration zone is a certain indication of water-logging by iron-containing ground waters. Many more examples of this type can be given.

Although it is possible to reveal the causes of water-logging by studying quite distinct indixes (soil genesis, geomorphological situation, climatic factors, lithological structure of the soil layer, etc.) and sometimes possible to make a quantitative estimate from study of the water balance of water-logged soils, their water-physical and other properties, the degree of water-logging is still often established purely on the basis of a visual and largely subjective study of the morphology of the soil profile. This approach is further explained by the fact that only one element in the continuous "soil — plant" chain is normally studied. In soil improvement and agricultural practice the "soil — crop" system is so intimately connected that there can be no justification for making a separate assessment of excess moisture in soils purely on the basis of a study of morphological characteristics. It is evident that a soil may show clear signs of water-logging and still not need draining because it is not too moist for a number of crops. Any description of the degree of water-logging should therefore be related primarily to the need to drain soil in relation to differing agricultural utilization.

There is, however, little information on the development of plants in water-logged soils. Afanas'yev (1) was one of the first investigators to pay attention to the need to collect information on the yield of different crops on water-logged soils and to evolve a production classification of the soils on this basis. He noted that yield should be assessed for these purposes in relation to annual precipitation (wet, dry, and average years).

Kasatkin (3) and Kasatkin and Pil'ko (5) have demonstrated that reduction in yield is often strictly related to the development of signs of water-logging in the soil. In a number of soils (podzolic, podzolic with signs of

Table 1

Outline of regional subdivision of water-logged soils of the non-chernozem zone for reclamation purposes

Soil reclamation district	Cause of water-logging	Soils and degree of water-logging			Texture of the horizons in soil profile and of the soil-forming parent material and subjacent rocks	Method (principle) of drainage	Agricultural use of the soils before and after improvement, properties, and sequence of draining	Grain yield after drainage, cntr/ha	
								Without application of fertilizers	After application of fertilizers
Soils of watershed									
District of soils of ground and hydrostatic water-logging	Ground and hydrostatic (allochthonous) waters	a) Soft	Podzolic	Deeply gleyed gley-like and gley	Mainly sandy and sandy-loam, rarely course and medium clay loam	Lower ground water level	Deeply gleyed and gley-type soils may be used as meadows of low productivity and less frequently as pastures in their natural state. Gley soils do not usually have agricultural value. The clay loam and sandy loam varieties that are less podzolized should be drained first. The draining of soils of sandy texture is not economically advantageous. Liming and the application of organic and mineral fertilizers is essential, especially fertilizers containing nitrogen and phosphorus. Phosphorites and green fallows should be used. Planning impossible. Tree roots can be grubbed out if organic and mineral fertilizers are used. Sandy soils are suitable for forest plantations.	2—3	12—18
			Sod-podzolic	Deeply gleyed, gley-like and gley				2—5	14—20
			Peaty-gley					3—5	18—22
		b) Hard	Dark sod-podzolic	Deeply gleyed, gley-like	Mainly clay loam		Deeply gleyed and gley-like soils are normally used without drainage as productive meadows, hayfields, and pastures. In their natural state gley soils provide pastures of low productivity. The drainage of all soils of this group is promising. Fairly low rates of fertilizer application are needed to bring the land under profitable cultivation. Liming is not indicated (except for podzolic soils in some cases). Soils underlain by compact limestones (at a depth of down to 30 cm) are unsuitable for agricultural use. Territories with such soils are excluded from intensive use.	6—11	18—25
			Dark soddy	Gley-like, gley				8—14	20—28
			Soddy-calcareous, leached	Deeply gleyed, gley-like				8—12	20—30

Table 1 (continued)

			Soddy-carbonate	Deeply gleyed, gley-like				9–14	22–30
			Humus-gley						
		c) Iron-containing	Soddy-ochreous	Gley-like, gley	Sandy and sandy loam, rarely clay loam	Lowering in ground water level, mechanical, and biological destruction of mineralized horizon	Can be used mainly as pastures of low productivity without drainage. Sequence of draining: soddy-ochreous and peaty-ochreous, soddy mineralized soils of sandy loam, and clay loam. Drainage of sandy soils is not very effective. Intensive agricultural use is not advised when the mineralized horizon is at a depth of between 0 cm and 30 cm. The mineralized horizon must be broken up when it lies between 30 cm and 70 cm. Drainage is only effective with full amounts of organic and mineral fertilizers, and liming. Retrogradation of phosphates is possible.	2–4	12–18
			Peaty-ochreous	Gley				3–5	14–18
			Soddy-mineralized	Gley-like, gley				2–3	10–16
District of surface water-logged soils	Surface (atmospheric, slope drainage and autochthonous) waters		Podzolic Sod-podzolic	Lightly gleyed medium-gleyed strongly-gleyed	Clay loam and clay (on acid moraine, mantle, ancient lacustrine, and other deposits)	Acceleration of surface and subsurface flow	Meadows containing moisture-tolerant perennial grasses (mainly cereal grasses) can be created on slightly gleyed soils without drainage. Slightly gleyed soils are normally used as pastures of low productivity or poor meadows. Medium gleyed soils can only be used as meadows of low productivity without drainage. Sequence of draining: firstly soils that are slightly podzolized and varieties of clay loams. Drainage is only effective when a full amount of organic and mineral fertilizers and liming are used (less lime should be used on soils formed on calcareous moraine).	4–5	16–20
					Clay loam and clay on carbonate moraine			5–7	18–22
			Podzolic		Sandy and sandy loam down to 1m-2m clay loam and clay below	Lowering of level of perched water (autochthonous)	Breaking up of the horizons beneath the plowing layer, mole drainage, and chemical and biological structure formation in the upper horizons are essential after drainage. Planning not possible. Trees should only be grubbed out when organic and mineral fertilizers are used.	2–3	12–18
			Sod-podzolic					2–5	14–20

Table 1 (Continued)

Soil reclamation district	Cause of water-logging	Soils and degree of water-logging		Texture of the horizons in soil profile and of the soil-forming parent material and subjacent rocks	Method (principle) of drainage	Agricultural use of the soils before and after improvement, properties and sequence of draining	Grain yield after drainage, cntr/ha	
							Without application of fertilizers	After application of fertilizers
District of soils of pedogenic water-logging	Soil-forming process	Podzolic	Slightly gleyed	Sandy and sandy loam down to more than 3m-4m. Water impermeable iron-containing layers in the first meter	Mechanical destruction of water-impermeable layers	Same for soils water-logged by soft groundwaters	2–3	12–18
		Sod-podzolic	Medium gleyed, strongly gleyed				2–5	14–20
District of soils of biogenic water-logging	Evolution of vegetation	Podzolic Peaty-podzolic	Slightly gleyed, medium gleyed	Mainly sandy loam, coarse and medium clay loam	Aëration of root layers and their enrichment with plant nutrients	Soils of extremely low fertility. No agricultural value in natural state. Plowing, deep harrowing, and the application of large amounts of organic and mineral fertilizers (phosphorites should be used) are essential for improvement	1–3 (possible absence of germination)	12–18
District of soils of anthropogenic water-logging	Man's agricultural activity	Podzolic	Temporary water-logging (without definite signs of gleying)	Clay loam and clay	Temporary measures to increase surface runoff. Creation of water-stable structure	Normally used as plowland. Rational agricultural use requires structuring of the upper horizons (chemical and biological), use of organic and mineral fertilizers, and liming. The use of more mobile agricultural implements is promising	4–8	16–20
		Sod-podzolic					5–9	18–22
Floodplain soils								
		Soddy-layered	Deeply gleyed, gley-like, gley	Series of sand and sandy loam interlayers		Deeply gleyed and gley-type soil varieties can be used as satisfactory meadow pastures without draining. Sequence of draining: "oölite" alder swamps, soddy granular layered, soddy layered, clayey peaty, soddy-gley. Sandy varieties of this group should not be drained for plowing owing to the danger of erosion	5–8	18–22
		Soddy-granular-layered		Clay and sandy loam interlayers			7–12	18–25

Table 1 (Continued)

Soil reclamation district	Cause of water-logging	Soils and degree of water-logging		Texture of the horizons in soil profile and of the soil-forming parent material and subjacent rocks	Method (principle) of drainage	Agricultural use of the soils before and after improvement, properties and sequence of draining	Grain yield after drainage, cntr/ha	
							Without application of fertilizers	After application of fertilizers
District of soils of ground and hydrostatic water-logging	Ground and hydrostatic (allochthonous) waters	Clayey-peaty gley		Alternating sandy, sandy loam, and rarely clay loam interlayers	Lowering ground water level	Sandy varieties can normally be used as plowland, as can selected sandy loam varieties (on elevations around water courses for vegetables that require warmth). Supplementary treatment of pastures with phosphates or potassium fertilizers is desirable; combined use of these fertilizers is rarely necessary. Soddy-layered soils do not need liming, the need for liming on other soils is governed by the chemical nature of the field waters in the basin. Improvement of the "oölite" soils of alder swamps is more difficult but most promising.	5–12	16–22
		Sod-gley					5–10	18–20
		"Oölite" soils of alder swamps		Mainly clay loam and clay			14–16	25–30
District of soils of surface water-logging	Surface (water course) waters	Soddy granular light brown	Deeply gleyed, gley-like, gley	Clay loam and clay. Often with buried peat	Lowering the level of perched water	Deeply-gleyed and gley-like varieties can be used as highly productive meadows and deeply-gleyed varieties as plowland without drainage. Gley-like varieties can be used for highly productive pastures with associations of large-stemmed grasses — sloughgrass, canary grass, reedgrass, etc.	7–10	18–25
		Soddy granular brown				Sequence of improvement: soddy dark brown, brown, light brown, granular soils and then clayey peaty and clayey-gley soils.	9–15	20–27
		Soddy granular dark brown				The best soils for vegetables are soddy-granular on buried peat. Light brown granular soils usually need liming, soddy granular brown, and dark brown soils do not.	11–15	22–30
		Clay-gley (compact)			Acceleration of surface runoff, aeration, lowering level of perched water	Clayey-gley, clayey-peaty-gley, and less frequently soddy granular gley soils may form compact dense horizons after drainage that the root system of plants has difficulty in penetrating. In this case mechanical and biological breaking up of the compacted horizons is essential. Mole drainage is effective.	4–6	8–16
		Clayey-peaty gley				Small amounts of organic fertilizers and top dressing with minerals (mainly potassium or phosphate minerals, rarely together) are advisable for all the soils of this group.	7–10	18–25

Table 2

Effect of the degree of water-logging of sod-podzolic soils on winter wheat yield. Shugarove Sovkhoz, 1960. (Yield estimated by sample areas)

Soil	Grain yield, cntr/ha		Wt. of 1,000 grains,g	
	Without top dressing	With mineral top dressing (N, P, K) in the tillering and boot stages	Without top dressing	With two top dressings
Sod-podzolic, well cultivated clay loam	34,0	35,8	40,2	40,9
Sod-podzolic, slightly gleyed, clay loam	6,2	12,0	39,0	40,0
Sod-podzolic medium gleyed, clay loam	4,3	11,8	27,5	30,9

Note: Comma represents decimal point.

water-logging, gley-podzolic, and podzolic-gley) Kasatkin noted a reduction in the yield of mixed clover and timothy from 326 to 100 cntr/ha (wet mass), of a vetch-oat mixture from 150 to 15 cntr/ha, and of spring wheat and oats for the first three soils respectively from 17 to 8.1 cntr/ha and from 15.2 to 11.5 cntr/ha.

The relationship between the winter wheat yield (Table 2) and the degree of water-logging of sod-podzolic clay loams by surface waters has been studied by the author of the present paper in joint experiments with V. G. Vinogradov in a district of the Moscow Oblast'.

These findings confirm that the yield of a number of crops is sharply reduced as the degree of water-logging increases. In the latter case it is essential to note that the use of mineral supplements (N, P, and K) gave some increase in yield as compared to the control. Nevertheless there is still considerable divergence between wheat yield on water-logged and non water-logged soil.

On the other hand, water-logging, which is usually poorly developed, does not retard the development of certain crops. Some crops even give higher yields on slightly water-logged soils. Afanas'yev (1) has established that "crops of flax, cabbage, and swede show a preference for a particular group of soils, the yield being highest on meadow-bog soils and then (in order of reducing yield) on peaty podzol, soddy podzol, and podzolic soil; the

Table 3

Differentiation of water-logged soils of the non-chernozem zone by the degree of water-logging processes

Soils water-logged by ground water and flood-plain structural soils water-logged by surface waters	Soils water-logged by surface waters (structureless)
1. Deeply gleyed. Drain only for ochards	1. Temporarily excessively wet. No apparent signs of water-logging. Suitable for various crops. Work with tilling, sowing and harvesting machines is difficult in monsoon districts in spring and autumn (or only in autumn).
2. Gley-like.[a] Drainage essential for most field crops and vegetables.	2. Slightly gleyed.[a] Should be drained for orchards and most field crops and vegetables. 3. Medium gleyed. Must be drained for artificial meadows and all field crops and vegetables.
3. Gley. Drainage essential for any crop.	4. Strongly gleyed. Must be drained for any crop.

[a] The following vegetables and field crops can be grown on gley-type and slightly gleyed soils without drainage: Cabbage, oats, vetch, peas, forage beets, swedes, and, possibly, flax.

reverse order of preference applies to potatoes".

Rosov (6) observed varying resistance of perennial grasses to anaerobic conditions on sod-podzolic gley clay loams. According to Seliverstov (7), oats are more resistant to flooding than spring wheat.

Our observations in the Moskvorets floodplain area enable us to assert that the same yield of forage beets (300 cntr/ha) and of cabbage (400-450 cntr/ha) was obtained in 1960 on gley soddy granular soils as on soils of this subgroup that were not water-logged.

There have been many cases of the failure of valuable meadow grasses following intensive drainage of meadows and pastures on slightly water-logged mineral floodplain basin soils. It follows from what has been said that classification of soils by degree of water-logging should be primarily related to the possibility of making agricultural use of these soils in their natural state.

The subdivision of soils by degree of water-logging given in Table 3 is fundamental to the grouping for reclamation purposes put forward in this paper.

Kasatkin (4) and others have shown that the development of gleying is largely controlled by the temperature conditions that govern the activity of the soil micro-flora and the rate of chemical reactions. Gleying is also intimately associated with the chemical composition and texture of soils and soil-forming parent materials, with the duration and time of occurrence of precipitation, and with other factors.

It can therefore be assumed that the morphological manifestation of anaerobic processes of the same duration will be different in the various natural districts of the zone and that, conversely, the morphological signs of gleying will be similar in soils in which anaerobic conditions are of different duration. It follows that the relationship between the morphological attributes of water-logging and the conditions of plant development should be separately established for the various climatic districts of the non-chernozem zone. The following example will illustrate the importance of this research.

In the European part of the Russian Soviet Federated Socialist Republic (RSFR), anaerobic processes in soils develop mainly in the spring and retard vegetation and sowing, whereas in the Far East anaerobic processes are most intense mainly at the end of the vegetation period, i. e., after the yield of many crops is already formed. Thus, whereas the group of natural factors that produce similar symptoms of water-logging may have a negative influence on the vegetative stage of crops and the formation of the harvest in the first case, causes that produce similar symptoms of water-logging in the second case will often not affect the formation of the harvest but will merely hinder its harvest. This circumstance has the important practical consequence that these soils can often only be incorporated in field crop rotations after drainage in the first case, whilst successful gathering of the harvest (especially of grain) on the morphologically similar soils of the Far East often only requires the use, as we have observed, of more mobile machines or simply of farming measures. It would therefore appear that the current subdivision of water-logged soils by the extent of gleying in the various horizons of the soil profile can be used for agronomical and reclamation work after it has been established that various types of crop can be grown on these soils.

In this connection it should be noted that the absence of distinct genetic horizons makes it difficult to distinguish soils by the degree of gleying in floodplain areas. Secondly, the initial stages in water-logging in the soils of the central floodplains, water-logged by surface waters are revealed by gleying of deep-seated layers in the soil profile and not by the appearance of signs of gleying directly beneath the accumulative horizon as in fine-textured podzolic soils (2). This is because soddy brown, dark brown alluvial clay loam, and clay soils,[1] which are of great economic importance in the non-chernozem zone, show a high tendency to

Table 4

Field moisture capacity of sod-podzolic and soddy granular (alluvial) soils as a percentage of total porosity in the 0 cm-30 cm layer

Soil	Degree of water-logging	FMC as a percentage of total porosity
Sod-podzolic, fine clay loam	Not water-logged	61,3
	Slightly gleyed	67,6
	Strongly gleyed	68,7
Soddy, granular, clay	Not water-logged	52,8
	Deeply gleyed	56,0
	Gleyed	57,0

Note: Comma represents decimal point

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[1] The names of alluvial soils are those given in Shrag's classification (8).

aggregate and to be water-permeable. Field water is therefore able to penetrate easily to the deep layers of the profile where it produces gleying. The well aërated upper horizons are a suitable substrate for sowing and planting the most varied crops and especially vegetables and grasses.

Drainage measures are largely conditioned by the genesis of water-logged soils, which governs their physical and chemical properties and therefore the position assigned to them in the regional subdivisions. Too little allowance is still made for this circumstance when planning drainage systems. The genesis of the soils and the properties evolved during their formation are not usually taken into consideration and allowance is only made for their texture.

The great importance of a correct understanding of those features of the water-logged mineral soils of the non-chernozem zone that are due to their origin can be illustrated by the example of fine-textured soils water-logged by surface downhill drainage and alluvial waters from water courses. It has been experimentally established that modern agricultural machines can till the soil when soil moisture is below 70%-75% of field water capacity. However, observation has shown that in water-logged sod-podzolic soils developed on mantle and moraine clay loams the moisture storage equal to saturation moisture capacity is 68%-69% and sometimes 70%-73% of total porosity in the upper 30 cm layer of plowland. Thus, when moisture is near to saturation capacity conditions become unfavorable to the use of machines on water-logged clay loam and clay sod-podzolic strongly and slightly gleyed soils.

In alluvial soddy granular fine-textured soils (Table 4) field moisture capacity is only 56%-57% of the total volume of pore space for the layer. With the same moisture, conditions are therefore more favorable for the use of machines and for the vegetative stage of crops on alluvial soils than on sod-podzolic soils.

The stability of mole drains can be determined on a large scale in the water-logged mineral soils of the European part of the RSFSR in the non-chernozem zone by a method developed by the author (10). The values collected (Table 5) confirm the previous hypothesis that mole drains normally silt up within a year in sod-podzolic soils of clay loam and clay texture. These drains are very stable in soddy granular alluvial soils of the same texture. Failures in the widespread use of this cheap and efficient method of soil improvement can probably be traced to the fact that only the texture of the soils and not their genesis was taken into account when constructing mole drainage. The values obtained show that whatever the texture of the soils podzol formation is one of the main causes for instability of mole drains in water-logged soils of watershed areas in the non-chernozem zone. Mole drainage is therefore usually efficient for such a short period in the podzolic and sod-podzolic soils of the zone that its construction is not economical. On the other hand mole drains often function for many years in the soddy granular soils of flood-plain areas although the conditions under which they function are not so favorable (Table 5).

Table 5

Results of mass[a] analyses of water-logged sod-podzolic and alluvial soddy granular and clayey-gleyed clay loams and clay soils for the percentage stability of mole drains

Type of soil	Mole drains functioned for			
	2–3 months	3-4 months - 1 year	2-3 years, rarely only 1 year	3-4 years or more
Alluvial	5,4	26,0	27,2	41,4
Sod-podzolic	64,2	27,3	8,5	—

[a] In all 110 samples were taken for each soil type in the various districts of the central non-chernozem zone.

Note: Comma represents decimal point.

One important condition for the successful functioning of drainage systems in fine-textured mineral soils water-logged by surface waters is that the material that fills the drainage trenches should be highly water-permeable. A potentially valuable method of increasing the water-permeability of this material is to add chemical structure-forming reagents (limestone, gypsum, polymers). It can be asserted on the basis of the research already carried out (11) that the properties of the soils, as a result of their genesis, must be taken into consideration as well as the properties of the reagent used.

It has been shown that limestone, gypsum, and calcium lignosulfate considerably improve the water-permeability of drainage fill from sod-podzolic soil and that gypsum is most effective. These reagents had a different effect on fill from alluvial soils, in which the addition of limestone and gypsum considerably reduced water-permeability by comparison with the control.

Finally it must be noted that these problems are so complex that the regional subdivision of water-logged soils for reclamation purposes here proposed can scarcely be taken as being fully developed. Further work is needed on many aspects including the classification of the soils under consideration, their site indexing, morphology, research on the development of various agricultural crops under anaerobic conditions of varying duration, and especially the relationship between methods of improving water-logged soils and their genesis, etc.

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SOILS OF THE CENTRAL PART OF THE KHANTY-MANSIYSK NATIONAL DISTRICT

S. S. MOROZOV, S. S. POLYAKOV, and G. M. TERESHKOV, M. V. Lomonosov State University, Moscow

The authors studied the soil of the Ob in the Surgut-Kondinskoye area in 1957-1958 during an expedition sponsored by the geological faculty at Moscow University. The area studied comprised the central part of the Khanty-Mansiysk National District, a territory approximately 700 km long and up to 100 km wide.

The territory is part of an extensive lowland plain slightly raised above sea level. The highest absolute altitudes (around 110 m) are found on the watershed plateau and the lowest (19.5 m) along the water line at its lowest points. The usual altitudes of the district are 26 m-32 m (bottomland) and 37 m-47 m (terraces). Surfaces are practically horizontal over most of the territory. There are enclosed depressions in places. There are water-barren horizons near the surface; surface runoff is slight and underground flow is impeded. Since precipitation is considerable and evaporation reduced, there are many lakes and extensive water-logged areas.

The following geomorphological elements can be distinguished in the relief: 1) the watershed plateau and 2) the valley of the Ob, consisting of third, second, and first terraces and bottomland.

The steep right hand slope of the Ob valley is formed by the watershed plateau in the area between Mt. Khanty-Mansiysk and the village of Kondinskoye. The topography of the watershed is ridgy or undulating and rises between 76 m and 89 m above the water line. Near the river significant amount of gullies dissect the surface. The third terrace is found in certain parts along the right bank to the north of Khanty-Mansiysk at heights of more than 30 m above the water line.

The second terrace can be traced along the left bank of the Ob at absolute altitudes between 35 m and 45 m. Its surface is mainly level but it slopes towards the river. Here and there the terraces are dissected by the valleys of small rivers and streams and by gullies.

The first terrace is continuous along the right bank of the Ob from Surgut to Khanty-Mansiysk and of intermittent occurrence along the left bank. The topography of the terrace is level and its absolute altitudes are between 27 m and 30 m. There is a well developed network of gullies on the slopes. In some places the surface of the terrace is slightly undulating and 2 m-3 m, rises alternate with bog depressions. The bottomland of the Ob is between 12 km and 35 km, wide, broken up by many large and small waterways and a considerable number of areas is under water. The bottomland is 3m-5m above the waterline and its surface is level except for occasional river banks and remains of the first terrace.

The climate is sharply continental: a harsh winter with continual snow storms and thick snow and a comparatively hot short summer. Mean annual temperature in the area is -1° to 3°C. Even in the warmest month (July) the temperature often falls from $+25^\circ$ to -1°C. Mean annual precipitation is 400-500 mm, least amount is in the winter (February) and most abundant in the summer (greatest in August). Between 75% and 83% of mean annual precipitation falls between April and October.

More than two-thirds of mean annual precipitation falls during growing period and this has a bad effect on the ripening of crops. The early and quite thick snow falls protect the soil from the effects of the harsh winter; this is one reason why permafrost is only found sporadically in peat bogs and on hillocks. The permafrost boundary lies somewhat farther to the north than in Eastern Siberia, where there is less snow.

The district studied lay within the coniferous taiga, where the dominant tree species are pine, cedar, spruce, fir, and larch. The landscape pattern is typically one of bogs and forests, the former being larger than the latter. The forests favor the higher areas along river valleys (known as "continents"), and ridges and hills between bogs on the watersheds. In the area of the Ob valley studied, the forests were mainly cedars on the left bank bank from Surgut to the mouth of Irtysh and pines along the right bank. To the north of Khanty-Mansiysk the surface of the original right bank is covered by spruce, cedar, and rarely pine. The surface of the left bank is particularly water-logged in this area; the forests are grouped in the river valleys where they are found on ridges and banks along the rivers. Here there are islands of forest on raised areas and on sandy and sandy loamy areas of watersheds. Slash fires cover large areas; here and also on cut-over areas the coniferous species are temporarily replaced by aspen and birch. Birch is plentiful in the bottomland, where there are also willow thickets that grow to a height of 6 m - 8 m.

Natural meadows are found mainly in the bottomland. In geobotanical composition the water meadows are either cereal grass-motley grass, vetch, sedge-canary grass, sedge, or motley grass. Grass vegetation is normally absent from the forest; the soil is densely covered by green mosses, forest litter, and ubiquitous clumps of ledum, bilberry, mountain cranberry, cloudberry, leatherleaf, and cottongrass.

The rocks of which the district is composed are mainly of Tertiary and Quaternary Age, with the latter predominating and emerging frequently at the surface. The main soil-forming parent materials of the Ob valley within the district studied are clay loams of the watershed plateau and alluvial clay loams of the terraces. The various facies of the bottomland alluvium form widely distributed clay loam deposits in the bottomland (6).

The mantles of clay loam of the watershed plateau are mainly bedded on boulder clay loam and are 8m-10 m thick. Boulders and pebbles accumulate at the foot of these deposits and the boundary with the subjacent layer is sharp. Isolated sand lenses and occasional brown sandy loam intercalations are found in the clay loam mantles above the boulder-pebble layer. The upper part of these formations has become highly loessial and differs noticeably in morphological characteristics from the lower part. The sand lenses and clay loam intercalations and the sharp transition to the subjacent horizons (5) all indicate that the loess-like clay loams and sandy loams were formed by water action.

The soil-forming parent materials of the watershed plateau are sandy loams and coarse and medium clay loams (2) in which the dominant fraction is coarse silt (44%-54%). The colloidal clay content varies between 6. 5% and 23%, but the range of variation is quite narrow (21%-23%) for medium clay loams. It should be noted that the coarser varieties are found in the lower horizons of the soil-forming parent material and the more dispersive varieties in the upper horizons. The mineralogical composition of the sand particles is shown in Table 1.

The predominating clay minerals are often weathered. There are small amounts of kaolinite and halloysite.

These deposits are only slightly salinized; the content of water-soluble salts is 1/100 of a percent and of carbonates not more than 1%.

The loess-like clay loams and sandy loams of the watershed plateau are permeable to water owing to the presence of macropores; the infiltration coefficient is approximately 1 m/day. Total porosity is 40%-50%. The whole layer of rock-forming parent material is not water-stable and its plasticity is slight. These formations occur widely on the right bank of the Ob from Khanty-Mansiysk to Kondinskoye.

In addition to the mantle deposits (loess-like clay loams and sandy loams) of the watershed plateau, loess-like clay loams and sandy loams are also common on the first and second terraces. The first terrace extends along the right bank from Surgut to the mouth of the Nazym river; it is of intermittent occurrence on the left bank since the second terrace is sometimes found between Surgut and Khanty-Mansiysk.

There is little difference in appearance between these rock-forming parent materials and those of the watershed plateaus. They are usually silty and slightly ferruginized; in natural outcrops they are divided by vertical weathering fissures into 2 m-4 m wide columns. They are thinner than the mantle deposits of the watershed plateau and do not have a boulder-bebble layer and merges gradually with the subjacent layers. Some surface areas consist of sandy and sandy loam varieties. All the surface formations were undoubtedly produced by water action.

Separate facies can be distinguished when these terrace and bottomland deposits are studied in greater detail. According to Kadkina (2) there are 7 facies types in the district that we studied, the commonest of which are cryptostratified clay loams and sandy loams, lens-like-stratified clay loams, and sandy loams and riverbed alluvium.

Since these facies are rock-forming parent materials for the terraces and bottomland we shall describe them separately.

The cryptostratified sandy loam and clay loam facies are largely found in the alluvial deposits and consist of dark grey to straw silty sandy loams and coarse clay loams. These are deposits containing macropores that are mainly vertical; Shantser (6) ascribes the presence of vertical pores to soil-forming process. The rocks are strongly ferruginized, as is revealed by the presence of rings, ellipses, and small lenses. Stratification is normally absent. During field observations the deposits were found to be of varying thickness (6 m, on the third terrace, 4m-5m, on the second and 2m on the first and on the bottomland).

Transition to subjacent layers is gradual except when the superjacent deposits are of coarser texture (sands). Deposits of the cryptostratified facies also occur widely on the bottomland where they differ from the same facies on the terraces in being cinnamon-brown in color with dark blue spots and in being more moist and porous.

In texture the deposits of the cryptostratified facies are coarse and medium clay loams. The predominant fraction is coarse silt (45%-60%); total absence of coarse and medium sand particles is a typical feature. Average porosity of the deposits if 40%. The mineralogical composition of the clay and sand particles is little different from that for the loess-like clay loams and sandy loams of the watershed plateau.

Table 1

Mineralogical composition of the soil-forming parent materials of the watershed plateau, 0. 25 mm-0. 01 mm fraction

Mineral	Depth from which samples taken, m							
	2,20—2,30		3,40—3,50		4,70—4,80		6,10—6,20	
	Diameter of fraction, mm							
	0,25—0,05	0,05—0,01	0,25—0,05	0,05—0,01	0,25—0,05	0,05—0,01	0.25—0.05	0.05—0.01
Heavy fraction								
	(0,60%)		(0,30%)		(2,20%)		(0,70%)	
Epidote	25,4	—	26,9	15,7	10,3	7,3	6,6	5,9
Garnet	10,3	—	7,3	0,5	2,0	2,0	4,2	—
Hornblende	10,6	—	29,5	48,5	32,4	24,4	19,9	27,3
Tremolite	1,7	—	7,1	1,8	0,6	—	0,5	0,7
Pyroxene	3,9	—	6,6	—	—	—	0,7	—
Ilmenite	19,7	—	3,0	—	0,4	—	0,7	—
Rutile	4,4	—	1,4	1,0	8,1	—	11,5	—
Sphene	2,2	—	2,0	—	0,2	—	—	0,2
Leucoxene	8,4	—	2,8	0,8	2,4	—	1,6	0,7
Limonite	7,9	—	6,8	26,0	39,8	58,5	50,1	49,2
Staurolite	0,5	—	0,2	1,5	0,9	2,0	1,2	4,4
Tourmaline	1,2	—	1,2	1,2	1,3	5,0	1,0	3,1
Zircon	2,2	—	0,8	1,0	0,4	—	1,2	2,9
Mica	0,4	—	0,8	0,2	0,9	—	0,4	5,9
Other minerals	—	—	—	—	—	—	—	0,4
Light fraction								
	(99,40%)		(99,70%)		(97,80%)		(99,30%)	
Quartz	89,0	99,0	96,5	95,0	97,2	94,0	97,5	95,0
Felspar	2,0	0,2	1,2	3,75	0,7	1,0	1,2	2,5
Mica	7,0	0,8	2,0	0,75	1,2	4,0	0,9	0,5
Rock	2,0	—	0,3	0,5	0,7	1,0	0,5	2,0

Note: Comma represents decimal point.

The facies of lens-like stratified sandy loams and clay loams is quite widely distributed in the bottomland and on the terraces; these deposits are 7 m-10 m thick. They consist of interbedding of whitish-gray light sandy loams and dark gray medium sandy loams. The layers are thin, horizontally undulating, and sometimes discontinuous owing to alternation of intercalations of different texture. Facies of this type are found among the bottomland formations along the banks of the Yuganskaya Ob tributary. The deposits are an intercalation of grayish-yellow slightly micaceous sand with gray or brownish-gray sandy loam that is moist, plastic, and ferruginous. The intercalations of sand, sandy loam, and clay loams are 10 cm-20 cm thick and the total thickness of deposits of this facies does not exceed 2m-2. 5 m.

The riverbed alluvium consists of small and fine-grained sands that are well washed and graded, slightly micaceous and ferruginized, and normally white or yellowish-gray in color. Bedding is horizontal or cross and the thickness of the deposits above the waterline is 5 m-7 m. The sand grains are well rounded and contain grains of dark-colored minerals.

The riverbed alluvium consists of monodispersive varieties in which the fine-grained fraction (0. 25 mm-0. 10 mm in diameter) predominates and varies between 76% and 92%; there are no 2 mm-0. 5 mm in diameter sand particles.

In addition to these facies, a varve facies, and a secondary reservoir facies are found on the surface of the terraces.

The varve facies has a texture in which intercalations of sand, sandy loam and clay loam alternate: this distinguishes it from the lens-like-stratified facies. The texture of these intercalations is little different from the similar intercalations in the facies of the cryptostratified and riverbed alluvium deposits. The secondary basin deposits consist of blue-gray fine clay loams that are strongly moistened and sticky. They occur widely in the inner zone of the bottomland and occasionally on the surface of the first, second, and third terraces.

Thus the soil-forming parent materials of the districts studied are of diverse lithological composition, ranging from medium clay loam to fine-grained sands. Clay loams, produced by the action of water, which has endowed them with distinctive lithological features, are the most abundant.

The two genetic soil groups established in this area of the Ob valley are podzolic and bog.

There is primary development of podzol formation beneath coniferous forest in the humid temperature summer. This leads to the formation of typical podzols on loess-like sandy and clay loams. The many subgroups, species, and varieties of this soil group differ in the thickness of the podzolized horizon owing to variations in the group of factors in the areas where the soils occur, especially in the access of light to the taiga, its species composition, and the presence or absence of a herbaceous vegetation (4).

Thick podzols are widely distributed on the sandy and sandy loam deposits of the first terrace distinguishes it sharply from all the other geomorphological elements. The forest here is 80% pine, there is no herbaceous vegetation beneath the forest canopy, and the podzolized horizon is covered by a dense carpet of forest litter 7 cm-10 cm thick. There is moss (sphagnum) where there have been forest fires and in bogs and there are low bilberries and mountain cranberries in open places.

The trees of the second terrace are shade-resistant conifers (spruce, cedar, and fir). Here the soil-forming parent materials are coarse and medium clay loam loess-like deposits that occur naturally under more moist conditions. A sparse but uniform layer of moss is a typical feature. Podzols of medium thickness covered with moss overlain by coniferous litter fall therefore develop here. There are occasional shrubs of ledum. Approximately 20% of the second terrace is bog.

The greatly dissected topography of the watershed plateau is covered by dense spruce-cedar taiga with a few firs and larches.

Since the soil-forming clay loams are continually water-saturated, the area is waterlogged. The soil and the parent material are gleyed at a depth of 1 m-1.5 m. The air in these forest is humid, the sun's rays do not penetrate and evaporation from the surface of the soil is very slight. The accumulation of moisture promotes the development of a thick carpet of moss which extends down to a depth of 30 cm. Thickets of ledum, mountain cranberry, and bilberry protrude above the moss.

The profile of the thin podzols on the watershed plataeu was found to be deeper than the profiles of medium and thick podzols on the terraces, although podzol formation is more intensive on the terraces. This thickness of the weak podzols may be due to their considerably greater absolute age. Vegetation, which is more luxuriant and varied on the watershed than on the terraces, has certainly affected the depth of the soil processes. The development of the podzolization process is here impeded by gleying and the clay loam texture of the soil-forming parent materials.

Active development of the podzolization process at the surface of the first and second terraces is accentuated by the coarse texture of the alluvial deposits and by the coniferous-birch forest.

The following genetic horizons can be clearly distinguished in the soil varieties of the podzol group.

A_0 forest liter of needles and twigs; 6 cm-8 cm on thick podzols, 10 cm-12 cm on medium podzols and up to 25 cm on thin podzols.

A_2 a whitish tinge and foliated structure are distinct and typical features of all the podzol varieties; the horizon is 5 cm-8 cm thick in thin podzols, 15 cm-20 cm in medium and 25 cm-45 cm in thick podzols.

The B_1 horizon is typically dark cinnamon-brown in clay loams and ochreous in sandy loams and is considerably compacted. In some cases there are no new formations in it, but in others ortsands account for the major part of the horizon which is 25 cm-32 cm thick. The B_2 horizon is typically lighter in color and more moist and it merges graudally with the subjacent parent materials. It is 30 cm-40 cm thick. The total thickness of the profile of these soils is 2.2 m on the watershed and 1.40 m-1.50 m on the first terrace.

Quantitative chemical analyses of these podzolized soils (Table 2) shows that there is accumulation of silica in the upper horizons and transport of sesquioxides to the lower horizons.

The full similarity between podzol subgroups is shown by the slight total content of humus (0.17%-0.47%) in the upper horizons of the podzols, its reduction down the profile, and the general total content of humus in the meter layer. The silica content of the podzolized horizon is of the same order (84%-87%; in the illuvial horizon it is only reduced by 4%. The total content of aluminum varies from horizon to horizon: the illuvial horizon contains twice as much as the A_2 horizon. There is little difference in the distribution of the iron oxides throughout the profile although there is a tendency for iron to accumulate in the B horizon. There is little calcium oxide in the soils (0.29%-0.98%) and even less of manganese oxide (0.02%-0.09%).

The exchangeable bases were determined by extraction with an 0.02 N solution of HCl and subsequent titration with trilon. Hydrolitic acidity was determined by Kappen's method and the pH values in water and salt extracts by the electrometric method.

It can be seen from Table 2 that these soils

Table 2

Chemical composition of the soils

Soil	Profile No.	Genetic horizon	Depth, cm	Humus content, %	Hygroscopic water	Ignition loss	Total composition, % of dry noncarbonate sample									Adsorbed bases, meq per 100 g of soil				Degree of base saturation, %	pH	
							SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	P_2O_5	K_2O	Na_2O	Ca^{++}	Mg^{++}	M. hydrolytic	Total		Salt	Water
Thick sandy loam podzol, terrace I	46т	A_2	22—32	0,47	0,46	1,27	87,53	6,75	Сл.	0,06	0,83	0,46	1,04	1,04	1,02	0,82	0,60	8,10	9,52	15,0	3,94	4,54
		B_1	40—50	0,19	0,48	0,53	83,69	11,34	0,80	0,06	0,63	0,41	0,03	1,09	1,11	0,78	0,41	6,13	7,21	17,0	4,14	4,64
		B_2	90—100	0,11	1,22	1,57	83,07	11,49	2,11	0,06	0,47	0,77	0,04	1,02	1,04	1,04	0,83	5,64	7,51	25,0	4,24	4,74
		C	120—130	—	1,03	0,44	81.90	13,04	1,93	0,03	0,41	0,54	0,06	1,00	1,00	2,30	0,98	5,51	8,79	37,0	4,34	4,94
Thick sandy loam podzol, terrace II	63т	A_2	20—30	0,38	0,84	1,80	85,25	7,63	0,68	0,08	0,88	0,33	0,06	1,06	1,96	1,10	0,43	7,90	9,43	16,0	3,34	4,24
		B_1	40—50	0,21	0,66	1,17	83,97	9,76	0,99	0,05	0,61	0,38	0,07	1,01	1,04	1,23	0,56	5,41	7,20	24,0	3,84	4,84
		B_2	60—70	0,29	1,17	1,51	81,17	12,09	2,07	0,06	0,29	0,58	0,04	1,03	1,11	1,03	1,57	5,10	7,70	33,0	3,94	4,84
		C	90—100	—	0,54	0,81	80,85	13,04	1,71	0,05	0,34	0,41	0,09	0,88	0,98	2,12	1,60	4,90	8,62	43,0	3,94	5,04
Medium coarse clay loam podzol, watershed plateau	49т	A_2	8—18	0,37	0,64	1,61	83,79	10,96	1,38	0,06	0.98	0,62	0,04	1,09	1,07	0,90	0,77	8,34	10,41	16,0	3,14	4,14
		B_1	25—35	0,08	0,88	1,44	80,63	13,34	1,62	0,08	0,97	0,47	0,02	1,09	1,14	0,73	0,80	6.90	8,43	18,0	3,94	4,94
		B_2	40—50	0,17	0,75	1,06	81,50	12,17	2,09	0,06	0,84	0,21	0,15	1,08	1,23	1,41	0,93	5,03	7,97	40,0	4,14	4,94
		B/C	80—90	—	0,60	0,93	80,50	13,51	1,62	0,05	0,77	0,34	1,08	1,03	1,01	2,10	1,27	5,12	8,49	39,0	4,24	4,84
Medium coarse clay-loam podzol, terrace I	73т	A_2	9—19	0,31	1,03	1,81	86,98	6,47	0,94	0,08	0,48	0,67	0,05	1,09	1,01	1,08	0,53	7,96	9,57	17,0	3,64	4,59
		B_1	40—50	0,16	0,81	1,24	84,93	8.55	1,26	0,06	0,61	0,49	0,04	1,10	1,12	0,88	0,91	6,50	7,79	23,0	3,94	4,84
		B_2	60—70	0,21	0,76	0,97	82,01	11,20	2,04	0,09	0,87	0,32	0,12	1,02	1,06	1,34	1,60	5,78	8,72	34,0	4,04	5,02
		C	140—150	—	0,90	1,08	81,27	13,04	1,19	0,07	0,74	0,41	0,07	1,03	1,01	2,60	1,17	5,11	8,88	42,0	4,04	5,24
Thin medium coarse clay-loam podzol, watershed plateau	51т	A_2	5—15	0,17	0,17	0,42	87,59	6,49	0,82	0,04	0,33	1,27	0,06	1,04	1,02	1,30	0,61	6,88	8,79	22,0	3,84	4,94
		B_1	50—60	0,23	1,17	1,66	85,75	9,61	0,86	0,06	0,39	0,27	0,05	0,71	0,94	1,05	0,60	5,30	6,95	24,0	4,44	5,04
		B_2	90—100	0,06	0,36	0,44	83,79	10,73	1,29	0,06	0,58	0,31	0,11	1,00	0,99	2,74	0,70	5,00	8,44	40,0	4,24	5,24
		C	120—130	—	0,55	0,59	82,84	12,23	0,91	0,07	0,42	0,34	0,07	0,98	0,01	4,08	1,05	5,81	10,94	49,0	4,54	5,44
Peat-podzol-gley medium-loam, terrace II	58т	A_2	50—58	0,80	1,60	3,90	89,91	7,56	0,91	0,02	0,96	1,11	0,03	0,17	0,90	1,40	0,90	6,10	8,40	30,0	4,24	4,64
		C	70—80	0,31	1,03	1,87	79,14	13,10	2,83	0,04	0,80	0,74	0,02	2,46	1,84	2,83	1,81	5,70	11,37	49,0	5,34	5,94

Note: Comma represents decimal point.

Table 3

Particle size analysis of soil, % of dry sample

Soil	Hole No.	Genetic horizon	Depth, cm	Thickness of horizon cm	Particle diameter, mm									
					>1	1–0.5	0.5–0.25	0.25–0.10	0.10–0.05	0.05–0.01	<0.01	0.01–0.005	0.005–0.001	<0.001
Sandy loam podzol thick	46т	A_2	22—32	8—35	—	—	5,11	14,68	15,99	48,12	16,10	9,57	4,77	1,76
		B_1	40—50	35—67	—	—	7,54	11,92	18,63	41,50	21,31	12,81	5,68	2,82
		B_2	90—100	67—104	—	—	9,45	19,56	24,40	29,75	17,84	11,05	2,99	3,80
		C	120—130	104—160	—	—	8,38	17,10	21,84	33,21	19,47	13,15	2,72	3,60
Sandy-loam thick podzol	63т	A_2	20—30	9—37	—	2,69	7,88	2,77	24,30	44,10	18,26	10,14	6,80	1,32
		B_1	40—50	37—56	—	0,58	5,90	1,91	18,40	50,81	22,40	14,30	5,75	2,35
		B_2	60—70	56—85	—	—	3,26	—	26,11	56,73	13,90	9,10	3,61	1,19
		B_2/C	90—100	85—130	—	—	2,77	0,74	14,93	61,80	19,76	11,50	4,46	3,75
Coarse clay loam medium podzol	49т	A_2	8—18	6—23	—	9,39	7,50	9,56	17,43	34,56	21,62	14,98	1,36	5,28
		B_1	25—35	23—37	—	1,30	5,15	6,92	12,84	48,46	25,33	19,62	2,84	2,82
		B_2	40—50	37—68	—	4,77	4,56	11,40	31,20	18,23	29,84	15,93	7,90	6,01
		C	80—90	68—140	—	0,93	7,13	13,86	24,71	27,19	26,18	9,57	12,47	4,14
Coarse clay loam medium podzol	73т	A_2	9—19	7—25	—	1,20	11,90	13,70	15,74	38,26	19,11	12,61	3,82	2,68
		B_1	40—50	25—53	—	2,67	6,81	9,33	11,28	45,18	24,83	15,36	4,71	4,76
		B_2	60—70	53—88	—	—	9,91	11,10	9,68	48,84	20,47	18,44	8,50	3,53
		C	140—150	88—170	—	—	5,71	16,74	14,20	35,74	27,65	13,10	7,31	7,24
Medium clay loam thin podzol	51т	A_2	5—15	5—15	—	1,00	5,12	14,51	12,80	31,77	34,80	12,55	18,40	3,85
		B_1	50—60	15—75	—	—	5,39	9,05	18,45	28,50	38,61	17,81	11,37	8,43
		B_2	90—100	75—110	—	0,55	6,18	6,57	9,90	34,25	42,54	24,10	13,60	8,84
		C	120—130	110—180	—	—	5,46	11,30	20,04	24,15	39,05	14,81	19,67	4,57
Fine clay loam, peat-podzol-gley	58т	A_2	50—58	50—58	—	—	2,53	4,81	10,74	18,57	63,37	9,00	16,24	38,11
		C	70—80	58—90	—	—	—	4,10	8,55	15,30	72,05	12,90	12,33	36,82

Note: Comma represents decimal point.

have a very low level of saturation owing to their insignificant content of adsorbed Ca^{++} and Mg^{++}. The A_2 horizon is the least saturated with bases (15%-20%); saturation increases with depth and reaches 37%-49% in the C horizon. The Ca^{++} and Mg^{++} content also increases with depth. Hydrolitic acidity is low within the profile but decreases uniformly. The reaction of the podzolic soils is very acid, as is shown by the pH of salt and water extracts.

Kachinskiy's method (1) was used to study the texture of the soils and his classification was applied to them. Both the podzols and the bog soils of the district are course and medium silty clay loam and silty-clay soils. It can be seen from Table 3 that at 60% the silt fraction predominates in the composition of the podzols. The clay fraction is only 3%-6% and the remaining 20%-25% is the sand fraction. The position is different for bog soils, in which the clay fraction predominates (40%-50%).

The mineralogical composition of the podzols in the district studied is shown in Table 4. It was determined from monoliths of the genetic soil horizons. Alluvial sands obtained from the 0.25 mm-0.05 mm and 0.05 mm-0.01 mm in diameter fractions were separated into a light and heavy fraction in a heavy liquid, after which the total number of mineral grains and the number of grains of each mineral were separately determined.

Bog soils. These soils occupy large extents of the watersheds and terraces. The bog type of soil formation is the principal type in the taiga belt in the north of the West Siberian Lowland. This wide distribution of bog soils is produced by heavy afforestation, the clay loam texture of the soil-forming parent materials, the great thickness and compaction of the illuvial horizon of podzols, excess moisture, and the thick carpet of moss. The wide variation in conditions has produced a great many subgroups and varieties of bog soils. Podzolic-bog soils are the most widely distributed subgroup followed by peat-gley soils of various types; peat soils are less widely distributed. The podzolic-bog soils of the watershed areas have clearly passed through a stage of podzolic soil formation in their development. Leaching regime was gradually destroyed by subsequent extension and compaction of the illuvial horizon of the podzols. Water-logging was facilitated by the excessive wetting of the subsoil. Peat and peat-gley soils occupy extensive areas on the first and second terraces. The origin of the peat bogs is associated with the growing over of lakes, old riverbeds, and other areas of stagnant water.

The peat soils of the district are developed on peat bogs up to 200 cm thick. We can only distinguish a single friable and excessively wet brown T horizon. The peat is 25%-35% decomposed. Nothing grows on these soils except a few species of bog pines and mountain cranberry thickets. The peat-gley soils have two horizons: a peat and a gley horizon. The T horizon may be as much as 70 cm thick, its cinnamon-brown upper part is poorly decomposed peat, while the lower dark cinnamon-brown part is more completely decomposed. The gley (G) horizon is grayish-blue, sticky structureless, and water-saturated.

Podzolic-bog soil varieties normally have three genetic horizons: peat, podzolic, and gley. They are divided into peat-podzolic-gley (T = 35 cm-60 cm) and peaty-podzolic-gley (T = 20 cm-35 cm) by the thickness of the peat horizon.

Table 4

Mineralogical composition of podzol fractions of between 0.25 mm and 0.01 mm in diameter (profile 49), % of total quantity of fraction with sp. g. > 2.75

Mineral	Horizon and depth, cm					
	A_2 20—30		B_1 40—50		C 110—120	
	Particle diameter, mm					
	0,25—0,05	0,05—0,01	0,25—0,05	0,05—0,01	0,25—0,05	0,05—0,01
Rutile	None	1,5	None	None	None	None
Garnet	"	1,5	"	2,0	"	0,5
Zircon	1,0	6,5	"	5,0	0,5	3,0
Tourmaline		2,0	"	Traces	None	
Hornblende	27,5	20,0	45,0	33,5	47,0	40,0
Pyroxene	5,5	None	None	1.0	None	
Epidote	None	"	"	None		2,0
Apatite	"	"	"	"		0,5
Muscovite	20,0	11,5	4,5	2,0	2,0	None
Biotite	8,5	2,0	9,5	6,0	5,0	3,0
Mica	7;5	9,5	9,5	7,0	10,5	11,0
Limonite	19,5	11,5	14,0	22,0	16,0	12,0
Ilmenite	8,5	14,0	16,0	8,5	17,5	23,0
Other minerals	2,0	20,0	1,5	13,0	1,0	15,0

Note: Comma represents decimal point.

Mention should be made of the general lack of alkali earths and alkali elements in the parent materials on which podzolic-bog soils are developed (Table 2).

It is evident from the chemical composition of peat-podzolic-gley medium clay loam that there is accumulation of silica (82.91%) in the podzolic horizon, and considerably less silica in the gley horizon (79.14%). The podzolic horizon is poor in aluminum and especially iron. There is also little iron ($Fe_{2}0_{3}$) in the G horizon but the alumina content ($Al_{2}0_{3}$) is almost doubled. The content of other elements ($Mn0$, $Ca0$, $Mg0$, $p_{2}0_{5}$, and $S0_{3}$) is also slight in them (normally tenths and hundredths of a percent). Mention should be made of the increased content of $K_{2}0$ and $Na_{2}0$ in these soils by comparison with the alkali earth bases ($Ca0$ and $Mg0$).

The hydrogen ion is greatly predominant over calcium and magnesium ions in the adsorption complex of these soils. The degree of base saturation increases in the lower genetic horizons.

The reaction of peat-podzolic-gley soils is less acid than that of podzols: pH = 4.6 in the podzolic horizon but is almost neutral (5.9) in the gley horizon.

The most important and widely distributed soils of the Ob bottomland basin are soddy-gley soils, subdivided into: a) soddy thin slightly gleyed soils, b) soddy medium thick medium gleyed soils, and c) soddy thick strongly gleyed soils; there are also soddy (meadow soils, soddy thin soils on stratified aluvium, and podzolic soils.

The bottomland soils have the following typical attributes: poorly developed genetic horizons, intensive staining of the whole layer by iron compounds as brown and ochreous patches, veinlets and intercollations, and ubiquitous manifestation of the gleying process (in varying degrees and at different depths) in the parent material and subjacent layer.

All the low lying areas of the bottomland, including the areas of stagnant water in the central area, are sod-gley soils which create the basic soil pattern of the district. The A_0 horizon of these soils in thin (2 cm-4 cm). The A_1 horizon is 25 cm-35 cm thick, structureless and compacted, and contains a mass of roots; it is moist, usually stained grayish-brown with a bluish tinge.

In the soddy horizon average content of humus is 5%, base saturation is 75%, and pH is 6. The texture is medium clay loam and the lower part is subject to gleying.

The gley (G) horizon is brownish-blue, sticky, fine clay loam; it does not contain humus; the degree of base saturation is approximately 70% and the reaction is slightly acid (6.3). The sod-gley soils are 50 cm-60 cm thick; the genetic horizons are very indistinct; they contain plentiful accumulations of manganic compounds. Gleying is usually developed in them from the surface down as patches and tongues and extends throughout the soil layer. Ground waters are to be found from a depth of 50 cm-80 cm.

The profile of thin soddy soils is divided into the following horizons by morphological structure: A_0 - 2 cm-3 cm thick, cinnamon-brown in color, and A_1 - 20 cm-25 cm thick, grayish-yellow variable color.

In texture they are usually medium clay loam, containing 3%-4% humus and the pH of the soil solution is 6.2. The B horizon is 10 cm-15 cm thick, normally grayish-brown, intensely iron stained, and medium clay loam in texture. Humus content is less than 1%, the pH is 6, and the degree of base saturation reaches 80%. The C horizon is a layer of grayish-brown bottomland alluvium of variable texture (alternation of clay loam and sandy loam is noticeable).

The maximum thickness of thin soddy soils is 35 cm-45 cm. Typical features are slight sodding from the surface, variable texture, friable structure, and intensive ferruginization. Ground waters are found from a depth of 0.8 m - 0.9 m. These soils are found over a considerable area of the bottomland on the elevated areas around the river.

The maximum thickness of sod-meadow soils is 45 cm-50 cm. Their horizons are: A_0 - 2.4 cm (sod); A_1 - 20-18 cm, gray color with a typical granular structure, medium clay loam. The B horizon is also approximately 20 cm thick, grayish-borwn in color, gleyed, medium clay loam. Humus content of the A_1 horizon in these soils is approximately 3.20%, decreasing to 0.60% in the B horizon. Mention should be made of the average adsorption capacity of these soils, which is 15 meg per 100 g, their considerable base saturation and the slightly acid reaction of the solutions.

In conclusion it should be noted that the sod-meadow soils, which do not require heavy expenditure for improvement, are the most suitable soil varieties for agriculture.

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GRAY FOREST SOILS OF PROLONGED SEASONAL FREEZING WITH A SECOND HUMUS HORIZON IN THE KRASNOYARSK KRAY

L. P. BUDINA, V. V. Dokuchayev Soil Institute, USSR Academy of Sciences

In the central part of the Krasnoyarsk kray a transitional zone between the forest-steppe and the taiga, consisting of herbaceous small-leaved forests, can be clearly traced to the north of the Achinsk, Krasnoyarsk, and Kansk island forest-steppes. In the west of the Kray it extends as a continuous belt between latitude 57° and 58° N, while in the east it is broken by the Yenisey Range and reappears to the north of the Kansk forest-steppe. Distinctive soils, with a second humus horizon, develop in this zone beneath the herbaceous small-leaved forests and are also found quite widely outside the Krasnoyarsk kray. An almost continuous belt can be traced from the Urals to the Yenisey north of the 57th parallel and extending approximately to latitude 58-60° N. These soils, which are widely known in the literature as secondary podzolized soils, have been studied and described by many workers (2, 4, 7, 6, 14, 13, 12, 11, 8, 1 etc.).

There are very few references in the literature to these soils within the Krasnoyarsk kray. Their distribution is mentioned by Petrov (14), who stated that their distinctive features were a clearly defined second humus horizon and high humus content and assigned them to the subgroup of gray forest soils.

I studied soils with a second humus horizon in the center of the herbaceous small-leaved zone in the Pirovskoye and Yeniseysk rayons on the left bank of the Yenisey between 57-58° N and 91-93° E. These rayons had not previously been the subject of special soil study, except for partial large-scale mapping of some kolkhozes in the Yeniseyssk rayon by the Krasnoyarsk Land Board.[1]

This territory is a rolling low hill plain in the eastern elevated sector of the Western Siberian Lowland. Watershed altitudes are highest (240 m-280 m) in the southeast and slope to the west and north-west to altitudes of 170 m-195 m. The plain is dissected very deeply (up to 50 m-90 m) by the Asymmetric valleys of the rivers Kem', Tyya, L. Belaya, Ket', and others. The topography is dissected the most around rivers.

The ubiquitous soil-forming parent materials are Quaternary light brown loess-like clays that form a continuous mantle on the watershed areas and on the upper terraces (above the third) of the Yenisey, Kem', and other rivers. Their features are: a) great thickness on the watersheds, where they form a 10 m-25 m mantle. On the upper terraces (above the third) they are between 1 m and 5 m thick; b) residual carbonate content. Carbonates are usually found at a depth of 120 cm-140 cm on the terrace clays, but have been leached to a far greater depth (250 cm-500 cm) on the watersheds. The carbonates are microcrystalline calcite.

Climate is sharply continental with a prolonged harsh winter. Mean annual air temperature is -1.7° C to -2.2° C and mean January temperature over a period of years is -20°C to -22°C. Precipitation varies from 380 mm (Pirovskoye) and 420 mm (Yeniseysk) to 520 mm (Losinoborskoye), increasing from south to northwest. The greater part of the precipitation occurs in the summer and autumn (June — September; 210-226 mm). The summer is warm and humid with continuous and sometimes torrential rain. Mean July temperature is +17.3° C to 17.8° C. Fog is common in the late summer and especially the autumn in the broad river valleys (Yenisey, Kem', and Ket'). The frost-free period is short (80 to 100 days) since there are frosts in the late spring (late May and early June) and in the early autumn (the beginning of September and occasionally early August). Snow settles after about the 10th of October and reaches a depth of 50 cm-60 cm in sheltered places and 30 cm-40 cm in open areas. Since the snow is relatively thin and winter temperatures are low, the soils freeze to some depth (120 cm-150 cm) and remains frozen for a long time (October to June). The biochemical and physico-chemical processes of these soils and their water and heat regime are basically affected by the late thaw and the slight heating of the soils. Veredchenko (20, 21) observed the formation of temporarily perched water above the frozen soil at a depth of 80 cm-100 cm in the spring of some years. This water disappeared within a week or two after total thawing of the frost layer. Below 80 cm-100 cm and down to 3 m-3. 5 m the profile of these soils consists of a cold, wet layer, the moisture of which is always equal to 90%-100% of field water capacity. Cryogenic gleying processes are produced in the soils by the continually wet layer and temporarily perched water.

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[1] This paper is devoted to the results of soil research carried out in these districts by the V. V. Dokuchayev Soil Institute as part of the Krasnoyarsk multi-purpose expedition of the Council for the Study of Productive Resources (USSR Academy of Sciences) in 1957-1958. The research was under the general direction of E. N. Ivanova and the section was headed by A. A. Yerokhina.

The basic soils of the rayon are gray forest soils of prolonged seasonal freezing with a second humus horizon, further divided by the degree of podzolization and humus accumulation into gray and light-gray forest soils. These soils form on level, slightly undulatings and gently rolling watersheds with deep ground waters (below 10 m-15 m) and on the high (3rd to 8th) terraces of the Yenisey and its tributaries beneath a canopy of sparse aspen and birch, birch and pine, and birch forests. Pine and birch forests often contain a sprinkling of larch. The forests beneath which gray forest soild develop have an abundant grass stand averaging 60 cm-90 cm high and often more than 100 cm. The extent of ground cover is slight (50%-60%), but the soil cannot be seen due to the profusion of the plant mass. There is an abundance of forest-meadow motley grasses (monkshood, crepis, hellebore, lungwort, paris, and sedge: the gramineous plants are represented by cocksfoot, meadow grass, and reedgrass). Other meadow-forest motley grasses they are found almost everywhere include birch vetch, peavine, burnet, globe flowers, and geranium.

These gray forest soils have a well-differentiated profile. Their humus horizon is approximately 15 cm thick, gray, densely penetrated by plant roots, and of fine nutty structure. The A_1A_2 horizon is light-gray with whitish flecks and of indistinct nutty structure in gray forest soils and platy-nutty in light-gray forest soils. The horizon occurs at a depth of 12 cm (15)-30 cm.

The second humus horizon (A_h) is very distinctly developed in the profile. It is normally gray or dark-gray with a bluish tinge and of nutty structure with relatively distinct upper and lower boundaries. It occurs at depths of between 30 cm (upper boundary) and 50 cm (lower boundary). This horizon is most clearly developed in gray forest slightly and medium podzolized soils. It becomes less distinct as the degree of podzolization increases.

There is a distinct bleached B_{1g} transitional horizon below the second humus horizon at a depth of 50 cm-60 cm. This horizon is bluish-brown with plentiful whitish powdering on the nutty faces of the structural units. In the dry state the B_1 horizon is very similar to a podzolic A_2 horizon and is only occasionally much lighter. Some investigators of these soils (especially Il'in [7]) have therefore treated their formation as being due to deep podzolization. This can clearly not be the only reason for the formation of the bleached horizon. Particle size analysis (Table 2) shows that there is little clay removal from B_{1g} (6%-10%), whereas the clay removal from the A_1A_2 horizon is of considerable magnitude (15%-43%). Micromorphological study also indicates that there is very slight removal from B_{1g} when it is compared with the superjacent horizons, especially A_1A_2. Thus, bleached areas from which the clay has been "washed out" are rarely found in thin sections of B_{1g}. Most of the pores, fissures, and cavities of this horizon are found to contain mobile sinter clay, indicative of the accumulation of clay.

Without denying the importance of removal processes in the formation of the bleached horizon, I tend to think that gleying processes, as a result of stagnation of the spring perched water table above the unthawed and therefore practically non-absorbing illuvial horizon, is of primary importance. Below there is a distinct illuvial (B_2) horizon that is brown, of prismatic-nutty structure, compacted, with a few rust-colored spots in its lower part (from a depth of 80 cm-85 cm). Infiltration capacity in this horizon is slight. When studying field water permeability Budina and Afonskiy found that the intake rate of the illuvial horizon in gray forest soils was very low (5 mm for a day) and that even this value was slightly exaggerated since trenching revealed that absorption of the water column on a watered surface was due more to lateral flow along the surface of this horizon than to soaking through.

The BC_g horizon can be traced between a depth of 95 cm and 130 cm. It is normally light-brown, of massive prismatic structure, moist, with intensive blue and rust-colored patches. Below 130 cm it gives way to a light-brown moist parent material with abundant blue and rust-colored patches. The intensive gleying and high moisture content of the lower part of the profile of gray forest soils of prolonged seasonal freezing with a second humus horizon is due to the prolonged retention at a depth of 120 cm-150 cm of a frozen layer which condenses and holds moisture. The presence of this layer leads to the formation of a highly wetted horizon (90%-100% of field water capacity) at a depth of 100 cm-350 cm with which the processes of seasonal gleying are associated.

Carbonates are usually leached to a depth of 250 cm-500 cm and often deeper. They are only found at a depth of 120 cm-140 cm in soils formed on younger surfaces (the terraces of the Yenisey and its tributaries). They occur as concretions, mealy patches, and saturated areas. The depth of effervescence is often the same as the depth at which carbonates occur in these forms. The fact that carbonate concretions often lie above the effervescence line of the fine earths indicates that leaching processes are taking place. This is also confirmed by micro-morphological analysis which shows that the carbonates with which the parent material is impregnated, i. e., present in the soil outside the concretions, can be seen with a microscope as compacted clusters round pores. These clusters do not merge gradually with the parent material as in carbonate formation, but are sharply separated from it, usually by fissures and cavities, owing to leaching of carbonates by descending flow.

It should also be noted that the parent

It should also be noted that the parent material is normally unevenly impregnated with carbonates. The three depths at which the maximum values are usually observed are 120 cm-140 cm, 250 cm-350 cm and 400 cm-450 cm. These maxima are clearly associated with the former levels of hard ground waters.

I shall describe the profile of one of these soils as an example.

Profile 352 was excavated in the Yeniseysk rayon 2 km to the southeast of Shapkino on a level watershed in a pine and birch forest with aspen undergrowth. The grasses, which were high and luxurious, consisted of hair grass, forest sedge, fern, cow vetch, geranium, monkshood, crepis, hellebore, bear's ear, and other motley grasses. Aspen in an open area were growing in a shallow depression on the level surface of the watershed. Gleying occurred from 80 cm as occasional rust-colored patches and from 100 cm as intensive blue and rust-colored concretions.

A_1	0 cm-12 cm	Gray fine clay loam, fine nutty structure, slightly moist, slightly compacted, thickly penetrated by plant roots. Noticeable transition.
A_1A_2	12 cm-23 cm	Whitish-light-gray fine clay loam with indistinct nutty structure, almost dry, slightly compacted, many fewer roots. Transition distinct.
A_h	23 cm-24 cm	Dark-gray fine clay loam with slight whitish powdering, nutty, damp, slightly compacted, few roots. Transition distinct.
B_{1g}	43 cm-60 cm	Bluish-brown fine clay loam, similar to clay, with intensive whitish powdering on the nutty facets of the structural units, damp, compacted with few roots. Transition distinct.
B_2	60 cm-100 cm	Brown clay, very compacted, prismatic-nutty, damp, occasional rust-colored patches from a depth of 80 cm. Noticeable transition.
BC_g	100 cm-130 cm	Light-brown clay, massive-prismatic, damp, with intensive blue and rust-colored concretions.
C_g	130 cm-600 cm	Homogeneous light-brown clay with intensive blue and rust-colored concretions, moist; moisture increases below 2 m and the soil becomes plastic.

The total root content in the gray forest soils with second humus horizon of long-season of freezing was determined by Kachinskiy's method. Samples were taken from each genetic horizon in the second half of August 1958. Table 3 shows the total quantity of roots since it was extremely difficult to divide them into living and dead roots. It was found that these soils contained a large amount of roots (39 to 40 metric tons/ha in an 0 cm-85 cm layer on virgin land and up to 24-25 metric tons/ha in an 0 cm-55 cm layer on continuously cultivated land -- (see Table 1). As would be expected the greater part of the roots (70%-80% of the total amount) is concentrated in the upper (0 cm-12 cm) humus horizon in which the processes of humus formation and accumulation of organic matter mainly occur. There is

Table 1

Total contents of roots and humus (metric tons/ha) in gray forest soils of prolonged seasonal freezing with a second humus horizon

Profile No.	Land use	Depth, cm	Roots	Humus
352	Virgin land	0—12	27,28	78,9
		12—23	5,24	37,5
		23—43	3,73	86,7
		43—60	1,79	26,9
		60—85	0,99	20,2
		85—100	Not det'd.	33,7
		In all	39,03	263,9
304	Idle	0—12	20,26	77,9
		12—25	1,69	35,1
		25—41	1,13	38,8
		41—55	1,37	20,5
		55—80	Not det'd.	31,0
		80—100		25,0
			24,45	228,3

Note: Comma represents decimal point.

Table 2

Basic chemical indixes of gray forest soils of prolonged seasonal freezing with a second humus horizon[a]

Profile No. and soil	Depth, cm	Hygroscopic moisture %	pH		Humus, %	CO_2, %	Adsorbed cations			Total of adsorbed cations	Content of adsorbed cations, % of total			Clay <0. 001 mm in diam.	Content of adsorbed cations; % of total
			Water	Salt			Ca^{++}	Mg^{++}	H^+ Gedroyts' m.		Ca^{++}	Mg^{++}	H^+		
352 Gray forest	0—12	3,17	5,1	4,0	6,64	None	17,8	2,7	1,0	21.5	83	13	4	16	46
	13—20	2,67	4,5	3,7	2,89	"	12,8	0,9	2,1	15,8	81	6	13	17	48
	25—35	3,60	5,3	4,0	3,36	"	16,5	1,6	2,5	20,6	80	8	12	22	50
	45—55	2,68	5,3	4,0	1,09	"	14,8	2,5	1,4	18,7	80	13	7	27	52
	80—90	3,94	5,6	4,0	0,88	"	17,5	3,3	0,5	21,3	82	16	2	41	67
	130—150	4,26	5,5	4,7	0,83	"	24,2	5,0	0,1	29,3	82	17	<1	42	72
	190—200	3,27	5,5	4,6	Not det'd.	"	19,0	3,3	0,1	22,4	84	15	<1	31	57
	250—270	3,25	5,5	4,6	"	"	19,0	3,3	0,1	22,4	84	15	<1	28	53
	310—330	3,53	5,2	5,1	"	"	19,5	2,9	0,1	22,5	86	13	<1	31	53
	370—380	3,27	5,4	4,8	"	"	17,4	1,7	0,1	19,2	90	9	<1	25	49
	430—450	3,05	5,2	4,6	"	"	19,0	3,3	Trace	22,3	85	15	None	30	55
	500—520	2,88	6,6	5,2	"	"	18,1	1,6	None	19,7	92	8	"	Not det'd.	
237 Gray forest	0—11	2,95	5.9	4,7	6,83	None	23,9	4,8	0,2	28,9	82	17	1	21	47
	11—21	2,73	5,2	4,2	3,71	"	20,3	2,4	0,8	23,5	86	10	4	23	55
	26—36	2,95	5,2	4,1	2,94	"	22,3	2,4	0,8	25,5	87	9	4	27	56
	40—50	3,27	5,1	4,1	1,22	"	20,8	2,4	0,2	23,4	89	10	1	32	61
	60—70	4,29	5,2	4,1	1,09	"	29,0	3,2	0,2	32,4	89	10	1	43	71
	100—110	4,08	6,4	6,2	0,77	"	30,8	3,0	None	33,8	91	9	—	40	70
	140—160	4,04	6,7	6,2	Not det'd.	Trace	Not det'd.			—	—	—	—	40	64
	200—220	3,37	6,8	6,4	"	1,19	"			—	—	—	—	33	58
	260—280	3,79	6,9	6,2	"	0,07	"			—	—	—	—	34	58
	320—340	2,73	6,7	5,3	"	None	"			—	—	—	—	27	54
	380—410	2.59	7.2	6.3	"	2,53	"			—	—	—	—	29	58
265 Light-gray forest	0—10	2,99	6,1	4,9	5,83	Not det'd.	24,1	5,4	1,4	30,9	79	17	4	21	57
	10—20	2,22	5,1	3,6	2,92	"	10,2	2,7	3,1	16,0	64	17	19	25	61
	30—40	2,42	4,8	3,6	2,81	"	14,4	2,9	3,1	20,4	71	14	15	26	55
	55—65	2,98	4,8	4,0	1,09	"	18,8	3,9	0,9	23,6	80	16	4	36	67
	85—95	3,84	4,9	3,9	0,75	"	25,4	5,4	0,5	31,3	81	17	2	47	74
	140—160	3,46	5,3	4,5	0,78	"	25,5	5,2	0,1	30,8	84	15	<1	42	70
	200—220	3,45	5,4	4,3	Not det'd.	"	24,0	4,8	0,1	28,9	82	17	<1	39	67
	260—280	3,18	5,4	4,7	"	"	23,5	3,7	Trace	27,2	86	14	Trace	39	65
	330—350	3,21	5,5	4,6	"	"	24,4	3,7	"	28,1	86	14	"	36	65

[a] The field material was analyzed in the Department of Soil Geography and Cartography's laboratory, V. V. Dokuchayev Soil Institute. The analysts included N. A. Andreyeva, K. Ya. Dorokhova, N. A. Kamennykh, V. F. Mochalova, N. A. Tyapkina, Z. S. Karayeva, G. Ya. Smirnova, and L. A. Bulayeva.

Note: Comma represents decimal point.

Table 3

Incomplete total chemical composition of gray forest soil of prolonged seasonal freezing with a second humus horizon (profile 352), % of ignited soil

Depth, cm	Hygroscopic moisture	Ignition loss	SiO_2	R_2O_3	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Total	Molecular ratios $\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{R_2O_3}$
0—12	1,44	10,67	71,73	20,48	16,60	3,88	2,24	2,21	0,59	0,84	98,09	7,4	49,3	6,4
12—23	2,07	5,75	71,58	20,84	15,90	4,94	2,04	2,08	0,94	1.60	99,08	7,7	38,5	6,4
25—35	2,35	6,36	69,14	22,15	16,63	5,62	2,29	2,23	1,20	1,77	98,78	7,1	32,7	5,8
45—55	2,46	4,34	67,42	24,26	17,94	6,32	2,09	2,72	1,09	1,51	99,09	6,4	28,3	5,2
80—90	3,53	4,38	65,10	26,70	19,27	7,43	1,89	2,57	2,19	1,87	100,32	5,8	23,4	4,6
130—150	1,81	5,00	65,92	26,08	19,14	6,94	1,76	2,44	2,17	1,84	100,21	5,9	25,3	4,8
190—200	2,84	4,10	67,76	24,78	18,45	6,33	2,17	2,21			96,92	6,2	28,5	5,1
310—330	3,04	3,94	66,59	24,98	17,96	7,02	2,31	2,42	2,14	1,91	100,35	6,3	25,3	5,1
430—450	2,92	3,92	66,77	24,06	17,46	6,60	2,09	2,40	2,32	1,84	99,48	6,5	26,9	5,2

Incomplete total chemical composition of clay fraction, % of the ignited soil

Depth, cm	Hygroscopic moisture	Ignition loss	SiO_2	R_2O_3	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Total	Molecular ratios $\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{R_2O_3}$
0—12	4,58	19,51	57,75	35,69	25,69	10,00	1,23	4,50	Not det'd.		99,17	3,8	14,6	3,1
12—23	6,73	16,30	55,29	38,71	26,60	11,91	0,78	3,39	"		98,37	3,5	12,4	2,8
25—35	7,80	18,00	53,87	41,43	29,36	12,07	0,45	3,07	"		98,82	3,2	12,0	2,5
45—55	8,09	11,36	54,86	40,61	28,23	12,38	0,34	3,51	"		99,32	3,3	11,8	2,5
80—90	7,54	11,13	54,37	40,48	27,92	12,56	0,99	3,75	"		99,59	3,4	11,5	2,5
130—150	8,43	8,87	55.03	41.60	28,99	12.61	0,33	3,37	"		100,26	3,3	11,6	2,6
190—200	10,44	11,28	54,53	40,51	28,13	12,48	0,51	3,23	"		98,78	3,3	11,7	2,5
300—310		8,02	55,49	39,07	26,59	12,70	0,32	3,21	"		98,09	3,5	11,6	2,7

Note: Comma represents decimal point.

a marked decrease in root content down the profile. Deep penetration of the root system is apparently impeded by late thawing in the spring and summer and because the temporarily perched water table creates conditions unfavorable to the development of root systems (anaerobiosis, gleying, etc.). In addition, plants probably have no need to utilize moisture from the deep horizons in view of the normally adequate moisture of the summer.

Calculation of top portion of plants in 1 x 1 m squares of forest meadow in the Pirovskoye and Yeniseysk rayon pointed to average values of 15-20 cntr/ha.

We shall examine the chemical properties of the soils being studied. The reaction of the soil solution is slightly acid (pH of a water extract 5.1-6.1; pH of a salt suspension 4.0-4.7) and acidity is highest in the center of the profile (pH of a water extract 4.6-5.2; pH of a salt suspension 3.6-4.1). In general the change in the reaction follows the pattern of base unsaturation, which is slight in these soils. Table 2 shows that the greater part of the adsorption complex is saturated with calcium and magnesium. The adsorbed hydrogen content (Gedroyts' method) fluctuates within the range 0.2 meq-3.1 meq or 1%-19% of the total of adsorbed cations.

Accumulation of exchangeable cations owing to the sodding process is to be observed in the upper humus horizon (relative to the eluvial horizon). There is no accumulation relative to the parent material.

Particle-size analysis reveals that there is a strong removal of clay fraction from the upper part of the profile (Table 2). Since the process occurs from the surface downwards, these soild contain little clay in the upper humus horizon despite the high humus content of the horizon: this is also the case in typical podzols.

Signs of the eluvial process are clearly revealed by the total chemical analysis. It can be seen from Table 3 that there is relative accumulation of silica in the upper part of the soil profile owing to removal of sesquioxides, which apparently accumulates in the center of the profile.

By comparison with the chemical composition of the soil as a whole that of the colloidal clay is subject to very slight change throughout the profile (Table 3). Certain alterations to the chemical composition of the colloidal clay fraction in the upper part of the profile can be treated as an indication of accumulation of silica in the ash of herbaceous plants and trees rather than as decomposition of the clay and differential removal of the decomposition products. This accumulation widens the $SiO_2:R_2O_3$ ratio.

Micro-morphological studies reveal a finely dispersed highly polarized mobile clay in the form of incrustations in pores, fissures and other soil cavities. The upper part of the profile in horizons A_1 and A_1A_2 normally contains a large amount of incrustation clay. Leaching patches bleached and devoid of

Table 4

Group and fractional chemical composition of the humus of gray forest soil of prolonged seasonal freezing with a second humus horizon (profile 352) (analysis by Tyurin's method)

Depth, cm	Organic carbon, % of total C of initial soil																		Total N in initial soil, %	N of residue, % of initial soil	$\frac{C}{N}$
	Total organ. C of initial soil, %	Substances extracted			Humic acid				Fulvic acid					Insoluble residue	Total		C of humic acids / C of fulvic ac			
		By alcohol-benzol	On decalcination	0.1 n H_2SO_4	Fractions				Fractions						Of humic acids	Of fulvic acids				
					I	II	III	Total	Ia	I	II	III	Total							
Upper humus horizon (0-12)	3,85	4.9	3,3	5,2	17,9	11,1	3,9	32,9	4,6	14,6	5,7	4,9	29,8	22,3	32,9	29,8	1,1	0,41	0,06	9,4
Second humus horizon (25-35)	1,95	6,1	1,8	4,2	25,6	28,0	8,8	62,4	5,1	9,2	2,8	2,8	19,6	12,0	62,4	19,6	3,3	0,17	0,03	11,5

Note: Comma represents decimal point.

clay predominate in these horizons. A considerable amount of mobile clay begins to reappear in the second humus horizon in which leached areas are far less plentiful. Clay was found to be highest in content in the upper part of the B_2 horizon (from particle-size analysis).

In view of the presence of mobile clay incrustations of slightly acid reaction and with a quite high level of base saturation (81%-99%) in these soils and in view of the relative constancy of the total chemical composition of the clay fraction through the profile, it can be assumed that the differences revealed by particle-size and total chemical analyses are not due to the decomposition of the clay, as was previously thought, but to illimerization. That these processes were possible in forest soils was first indicated in the Soviet literature by Glinka (5) and Fridland (3). Kundler (10) discovered illimerization processes in the sod-podzolic soils of the Moscow Basin and in the gray forest soils of the Tula forest reserves.

Chemical analysis revealed a high humus content in the upper horizon (up to 6% to 7%) in the gray forest soils being studied (Table 2). The decrease in humus content down the profile is quite gradual. In the light-gray forest soils the decrease is somewhat more abrupt, but humus is found at a considerable depth in both soils. It was found from analysis of the group, and fractional chemical composition of the humus of these soils (by Tyurin's method), that large amounts of the humus in the upper horizons can be extracted by direct treatment of the soil with an 0.1 N NaOH (Table 4). Thus, more than 50% of the total content of humus acids consists of the first fraction, namely humic acids of relatively simplified structure occurring in the free state of linked to free sesquioxides. There is considerably less (30%) of the second humic acid fraction extracted from the soil after decalcification and consisting of forms bonded with Ca and Mg. The first fraction is also dominant in the fulvic acids. It is apparent that this nature to the fractional composition of the humus is due to the special hydrothermal conditions of humus formation in the region. It has been shown (9) that the accumulation of complex forms of humus is most favored by the rhythmic alternation of a period of moistening that promotes active micro-biological activity followed by a period of moisture deficit in which activity is depressed. New formation of humus substances takes place in the first period and these substances become more complex and react with the mineral part of the soil in the second period. Slowing down of the further development of new humic matter is probably the reason for the predominance of free and relatively simplified humic acids in these soils.

The extent of the humus profile and the slow decrease in humus content through the profile in gray forest soils with a prolonged season of freezing by comparison with the gray forest soils of adjacent districts of the Krasnoyarsk kray (17) are due to the presence of a second humus horizon in the profile of these soils. This is normally not revealed when determining humus. Thus, it was only possible to detect 0.8% more humus in horizon A than in horizons A_1A_2 in 1 out of 15 profiles analyzed, although the color of the second humus horizon was usually much more intense than that of A_1A_2 and even of the upper humus horizon.

There are two explanations in the literature for the incompatability between the intensity of coloration of the soil and its percentage content of humus. The first suggests that the fault lies in the methods of determining humus, in which the amount of carbon is multiplied by the same standard coefficient for all soils (7); the second suggests that there is a difference in the types of humus compounds in the upper and lower horizons (18, 1).

Our studies of humus composition in the upper and second humus horizons confirm the latter hypothesis. It is evident from Table 4 that although the total content of fulvic acids is significant in the humus of the upper horizon, humic acids of fraction I predominate. There is far less of fraction II of the humic acids (Table 4). Humic acids also predominate over fulvic acids in the humus of the second humus horizon, but the relative content of the former is greatly increased. Whereas the ratio of humic acids to fulvic acids in the upper humus horizon is 1:1, it is 3:3 in the second humus horizon. Moreover, the content of fraction II of the humic acids bonded with Ca and Mg is considerably increased in this horizon.

There are two concepts on the origin of the second humus horizon. The first concept asserts that it is a relict of a steppe or meadow-steppe process of soil formation (2, 4, 6, 7, 13, 12, 8, 1, etc). The second concept treats the formation of the second humus horizon as being the result of a recent process of the inwashing of organic matter (11). Although we were not especially concerned with the origin of the second humus horizon, we have found in field and laboratory research that the depth at which this horizon occurs is relatively constant throughout its distribution (in all elements of the relief), except in depressions where it is a little lower, and that is always has sharp upper and lower boundaries and differs fundamentally in composition from the humus of the upper horizon.

On the basis of the above-mentioned facts, we assume that the second humus horizon is a relict of a type of soil formation differing from the recent type. This is supported by paleogeographic data (16, 15) which indicate that the soils of this territory have undergone a bog-steppe stage in the post-glacial period. Thick dark (bog, meadow-boggy, and meadow-steppe) soils developed at this time. With the commencement of a warmer and more humid period the upper part of the humus horizon was degraded by the forest vegetation that replaced the bog-steppe vegetation.

Conclusions

1. Gray forest soils of prolonged seasonal freezing with a second humus horizon are formed in a sharply continental climate — prolonged severe winter and short frost-free

period.

2. The soils are frozen to some depth and for a long period by the low winter temperature. This has a basic effect on their water and heat regime in the formation of temporarily perched water above the frozen layer and in the existence of a cold, continually wet horizon constantly at 90%-100% of field water capacity in which conditions favor the development of gleying processes. Cryogenic gleying processes are so widely developed that it seems legitimate to suggest that one should distinguish a province of soils of prolonged seasonal freezing.

3. After consideration of the chemical properties of the soils (slight acidity, fairly high level of base saturation, and relatively constant total chemical composition of the clay fraction throughout the profile) and of micromorphological research (the existence of clay incrustations in the soils), we would most tenatively suggest that differentiation of the profile is due to the process of illimerization rather than to decomposition of the clay.

4. Existing information (visual observations, group and fractional composition of the humus, and paleogeographic data) prompts the conclusion that the second humus horizon is a relict of the thick humus soils of a previous and different type of soil formation.

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MOISTURE REGIME OF A GRAY FOREST SOIL SOWN TO CORN AND WINTER RYE IN YEARS OF WET AND DROUGHT

R. K. DAUTOV, Institute of Biology, Kazan' Filial, USSR Academy of Sciences

Soil moisture is a basic factor in soil fertility. Although many works have been devoted to the moisture regime of various soils, further detailed study is required. The moisture regime of the soil varies in relation to the genetic features of the soil, the nature of the vegetation, climatic conditions, farming practices and particular cultivated crops.

Most of the work on the moisture regime of soil has been carried out in districts of drought, where the problem of supplying crops with the optimum amount of moisture is of particular importance. This problem is also a serious one for agriculture in the Volga-Kama forest-steppe where the climate is highly variable (13). Nevertheless, very little work on the moisture regime of soils in this region has been published.

The present paper is devoted to the results of a two-year study of the moisture of a gray forest soil sown to corn and winter rye on the "Druzhba" kolkhoz in the Vysokogorsk rayon of the Tatar ASSR. The area of the observations was on a high watershed plateau. The ground water was at a depth of more than 10 m.

I have already described the agrochemical and water-physical properties of the soil of this experimental plot in detail in another paper (4) and shall therefore restrict myself to a brief account of data for those properties that are essential to the present paper. Some of the moisture properties of the soil are given in Table 1.

In texture the soil is clayey-silty fine clay loam, loam, giving way below to coarse clay. Since the ground waters are deep, the main sources of moisture in the soil are its spring moisture content and the precipitation during the growing season. Precipitation values are given in Table 2.

It can be seen from Table 2 that there were quite widely differing amounts of precipitation in the growing season in 1956 and 1957. The former was a year of heavy rainfall, especially in July and August, while the latter was quite dry, except in August.

Soil samples for field moisture determination were taken in layers 10 cm thick as follows:

0 cm— 20 cm	8—10 samples
20 cm— 60 cm	5—6 samples
60 cm—200 cm	4 samples

The field moisture of the soil down to a depth of 1 m was determined every ten days throughout the growing season. At some periods, soil samples were taken down to a depth of 2 m. During this work we tried to find how the moisture requirements of corn were satisfied when it was being grown on gray forest soil.[1] To this end, and in the light of the capacity of corn to concentrate a large part of the precipitation around root collar of the plants (7), the soil samples for field moisture determination were taken from the region in which roots are most plentiful — 10 cm from the plants. At certain periods, soil moisture was determined both around the plants and between the rows (Table 3).

Table 3 shows that, in addition to the concentration of precipitation around the root collar of the plants, there is intensified consumption of moisture from a small volume of soil in the hill that contains the greater part of the root mass. During a dry spell there is, therefore, considerably less moisture in the hills than between the rows. This difference is stabilized after rain.

Consequently, moisture is unevenly distributed in the corn field, but this unevenness is only found in the upper soil layers (0 cm-30 cm). This is because the greater part of the root mass, as revealed by a study of corn roots in the soil of an experiment plot, is contained in the 0 cm-30 cm soil layers.[2] In the deeper soil layers there was no difference insofar as the moisture content of corn hills and between the rows was concerned, due to a sharp reduction in the water used by the plant roots and due to the horizontal movement of the water.

In view of the above, it was thought possible to extend the results obtained from moisture determination in the soil of the corn square-hills

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[1] Square-hill planting — 70 x 70 cm between hills.

[2] Distribution of corn roots in the soil was studied by F. D. Samuilov.

Table 1

Some soil and hydrological constants of gray forest soil, mm

Thickness of layer, cm	Wilting moisture (WM)	Moisture of broken capillaries (MBC)	Field moist. capacity (FMC)
0—20	26,2	53,5	76,5
20—50	50,8	75,0	95,7
50—100	104,8	142,0	180,4

Note: Comma represents decimal point.

Table 2

Precipitation (mm) in the growing seasons of 1956 and 1957

10 - day period	1956					1957				
	May[a]	June	July	Aug.	Sept.	May[a]	June	July	Aug.	Sept.
I	8,0	32,1	31,6	34.4	37,7	None	4,2	3,4	31,3	12,6
II	28,0	1,4	65,4	31,9	—	None	8,3	None	45,1	—
III	11,0	6,8	55,0	8,3	—	18,2	29,3	None	15,5	—
Total for month	47,0	40,3	152,0	74,6	—	18,2	41,8	3,4	91,9	—
Same, av. of per. yrs.	33,0	51,0	51,0	51,0	—	33,0	51,0	51,0	51,0	—

[a] The amount of precipitation between June and September was measured with rain gauges on the experiment plot. The values for May and the monthly averages over a number of years were supplied by the nearby Meteorological Station at Arsk.

Note: Comma represents decimal point.

Table 3

Moisture of gray forest soil in corn hills and between the rows, mm

Date of determination	Sample taken from	Thickness of layer, cm		Remark
		0—30	30—60	
July 24, 1957	Hill Between rows	55,3 68,6	93,3 95,9	Determined after a prolonged dry spell (there was hardly any precipitation in July)
August 23, 1957	Hill Between rows	91,1 91,3	99,3 99,2	Determined after plentiful rainfall (76. 4 mm between August 4 and 20)
August 31, 1957	Hill Between rows	71,1 76,8	96,3 97,3	There were 15. 0 mm between August 23 and 31 (31. 7 mm on August 27 and 1. 3 mm on August 28)

Note: Comma represents decimal point.

to the corn field as a whole, with the single qualification that moisture content in the 0 cm-30 cm soil layers will be somewhat greater between the rows during a dry spell than is indicated by the values given here.

The values for field moisture of a gray forest soil under corn and winter rye during the 1956 and 1957 growing seasons (in millimeters of a water column) are summarized in Table 4 and in Figure 1.

Examination of Table 4 and of curves A and B of Figure 1 indicates that the moisture content of the soil is dependent both on the amount of precipitation and on the type of cultivated crops being grown, and that this relationship can be observed down to a depth of 2 m.

The greatest change in soil moisture content in the two years was naturally observed in the plowed layer (0 cm-20 cm). In 1956, which was a wet year, there was considerable divergence between alteration in moisture content in the 20 cm-50 cm, 50 cm-100 cm, and 100 cm-200 cm soil layers beneath corn and winter rye (Table 4). In the corn fields the alteration in moisture content in the 20 cm-50 cm and 50 cm-100 cm layers was similar throughout the growing season to its alteration in the plowed layer, but in the winter

Table 4

Moisture of gray forest soil, mm

Thickness of layer, cm	Date of determination. Wet year of 1956													
	May 9	May 19	May 30	June 9	June 19	June 29	July 11	July 21	July 31	Aug. 10	Aug. 20	Aug. 30	Sept. 13	—
	Corn field													
0—20	57,8	62,1	54,2	69,5	50,6	49,0	61,2	73,9	78,7	74,9	78,0	72,1	75,9	—
20—50	93,8	97,5	89,2	101,7	79,1	84,5	87,2	99,4	101,0	92,7	96,7	90,8	94,6	—
50—100	160,0	167,3	157,4	166,1	144,5	153,9	157,5	167,9	177,1	172,7	174,1	178,5	173,9	—
100—200	—	—	297,5	—	—	—	—	—	331,9	—	—	—	35	—
	Winter rye field													
0—20	57,4	59,1	45,2	52,1	32,2	31,4	43,3	65,7	70,0	66,7	71,3	66,0	66,3	—
20—50	89,1	94,3	85,3	77,9	75,1	73,2	64,3	90,7	100,9	95,4	94,8	91,2	94,7	—
50—100	168,0	170,4	167,0	157,2	143,9		143,1	143,1	165,5	177,9	177,0	Not det'd.	175,4	—
100—200	—	—	273,4	—	—	—	—	—	270,7	—	—	—	296,4	—
	Date of determination. Dry year of 1957													
	May 3	May 10	May 20	May 30	June 10	June 20	June 30	July 10	July 20	July 30	Aug. 10	Aug. 20	Aug. 31	Sept. 15
	Corn field													
0—20	64,1	55,4	49,1	52,0	49,3	50,0	56,2	46,1	37,8	31,8	53,0	67,7	47,4	45,4
20—50	93,0	91,3	91,7	86,4	90,0	88,2	87,2	84,5	79,8	79,1	69,5	82,6	83,8	73,9
50—100	172,2	176,4	171,4	171,9	171,2	172,3	171,2	169,4	169,2	167,9	156,7	158,9	160,6	155,6
100—200	283,0	—	—	295,2	—	—	—	—	—	—	—	—	—	293,4
	Winter rye field													
0—20	70,0	52,1	34,3	34,1	28,1	31,1	42,1	33,9	28,1	23,6	51,4	72,6	Not det'd.	
20—50	103,8	89,5	76,7	72,9	72,0	65,4	65,1	59,0	63,3	60,7	64,8	78,8	"	
50—100	172,7	170,4	162,0	164,1	159,3	149,1	143,7	141,6	141,7	142,5	142,7	144,1	"	
100—200	315,4	—	—	308,8	—	—	—	—	—	294,0	—	—	"	

Note: Comma represents decimal point.

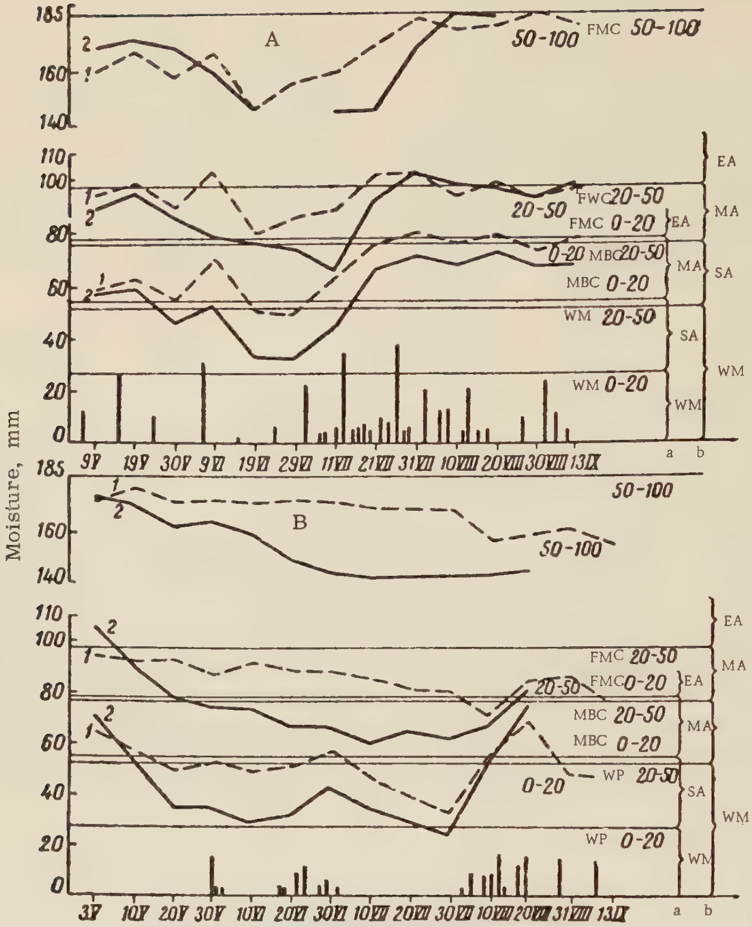

Fig. 1. - Change in the moisture content of gray forest soil. A - corn and winter rye fields in the wet year of 1956. B - corn and winter rye fields in the dry year of 1957.
1 - corn; 2 - winter rye; a - for the 0 cm-20 cm layer, b - for the 20 cm-50 cm layer. The vertical lines show the amount of precipitation (mm), and the horizontal lines show the soil and hydrological constants (mm) for the various soil layers. A - availability (EA - easily available, MA - moderately available, SA - slightly available); FMC - field moisture capacity; MBC - moisture of broken capillaries; WM - wilting moisture.

rye fields (from May 19 through July 11), there was a continuous reduction in moisture content. Consequently, all the precipitation that fell in this period failed to penetrate to the deep layers (below 20 cm) in the rye field and was expended in plant transpiration and in surface evaporation from the soil. When depletion of the reserve moisture in the meter layer on May 19, is added to this, the total loss of moisture from this soil layer in the rye field is 156.0 mm between May 19 and July 11 (82.9 mm of precipitation + 73.1 mm loss of reserve moisture from the soil).

Moisture losses from the same layer over the same period in the corn field were 103.9 mm (82.9 mm of precipitation + 21.0 mm loss of soil moisture reserves), i. e., 52.1 mm less than in the case of rye. This difference is entirely accounted for by the great loss of moisture reserves from the soil in the winter rye field.

A great difference was observed between corn and winter rye in the depth to which precipitation penetrated into the soil. Soil moisture determinations down to a depth of 2 m on May 30, July 31, and September 13, 1956, (Table 4) show that there was an increase of 34.4 mm in the moisture contents of the 100 cm-200 cm layer of the corn field between May 30 and July 31, and a decrease of 2.7 mm i. e., practically no alteration, in the rye field.

In the following period (July 31 to September 13), there were increases of similar magnitude (20. 6 mm and 25. 7 mm) in the corn and winter rye fields. The moisture reserves in this soil layer were 56. 1 mm greater in the corn field than in the winter rye field on September 13.

Owing to the abundant precipitation from July onwards, there was no difference in moisture content in the 20 cm-50 cm and 50 cm-100 cm soil layers between the two fields in August and September, since the moisture of these layers was very close to field moisture capacity. The slightly higher moisture content of the 0 cm-20 cm soil layer in the corn field at this time is due, as mentioned previously, to the capacity of corn plants to concentrate precipitation in the root collar, assisted by the large leaf area of the plants at the time.

On turning to the corresponding values for the dry year of 1957 (Table 4), we notice certain features in common with 1956; 1) considerably higher moisture content in all soil layers in the corn field than in the rye field until August and 2) considerably more intensive moisture loss in the first half of the summer from the soil in the rye field than from the soil in the corn field.

During this year there was continuous reduction in the moisture content of the soil in the rye field from May 3 to July 30 in the 0 cm-20 cm layer and to July 10 in the 20 cm-50 cm and 50 cm-100 cm layers. With allowance for precipitation, total moisture loss from the soil in the rye field during this time was: 109.8 mm for the 0 cm-20 cm layer; 44. 8 mm for the 20 cm-50 cm layer; and 31. 1 mm for the 50 cm-100 cm layer. The corresponding values for the corn field were 95. 7 mm, 8. 1 mm, and 2. 8 mm for the three layers.

It should be noted that no replenishment of the moisture of the deep layers (20 cm-50 cm and 50 cm-100 cm) by precipitation was observed between the beginning of May and the end of July of 1957. The entire precipitation was therefore applied to the plowed layer (0 cm-20 cm) in the calculations above. This was made for corn and winter rye.

These data show that there can be considerable differences to the total moisture loss from the soil beneath corn and winter rye at different growth periods. The meteorological conditions in the growing season have a considerable effect. This is confirmed by the values in Table 5.

It can be seen from Table 5 that the moisture loss from the soil during the period under consideration is considerably greater in land sown to winter rye than in land sown to corn in both a dry and a wet year. The values for 1956 show that moisture loss from the 50 cm-100 cm layer was almost the same for both crops. In the 0 cm-50 cm layer, on the other hand, the loss from the winter rye field was almost one-and-a-half times the loss from the corn field. The picture was quite different in the dry year of 1957, when moisture loss from the 0 cm-50 cm layer was slightly greater in the corn field than in the rye field. Moisture losses from the 50 cm-100 cm layer were more than five times greater in the winter rye field than in the corn field.

There are the following reasons for the differences already noted in the moisture regime of soils sown to corn and winter rye in the two years 1956 and 1957:

1) the different amount of moisture required by the plants at different stages in the growth

Table 5

Total loss of moisture (mm) from the soil between May 30 and July 30 in the wet year of 1956 and the dry year of 1957

Crop	Thickness of layer, cm	Total moisture content on May 30	Precipitation between May 31 and July 30	Residual moist. content on July 30	Total output of moist. between May 30 - July 30
		1956			
Corn	0—50	143,4	116,7	179,7	80,4
	50—100	157,4	41,2	177,1	21,5
	0—100	300,8	157,9[a]	356,8	101,9
Winter rye	0—50	130,5	169,9	170,9	129,5
	50—100	167,0	22,4	165,5	23,9
	0—100	297,5	192,3	336,4	153,4
		1957			
Corn	0—50	138,4	45,2	110,9	72,7
	50—100	171,9	—	167,9	4,0
	0—100	310.3	45,2	278,8	76,7
Winter rye	0—50	107,0	45,2	84,3	67,9
	50—100	164,1	—	142,5	21,6
	0—100	271,1	45,2	226,8	89,5

[a] Of the total precipitation to fall on the corn field between May 31 and July 30, only the amount that penetrated into the 100 cm-200 cm soil layer is taken into consideration (see Table 4).

Note: Comma represents decimal point.

of corn and winter rye. Winter rye makes its greatest demands on soil moisture in May and June, while corn makes its greatest demands in July and August. Loss of moisture from the meter layer of soil is therefore greater beneath winter rye than beneath corn at the beginning of the summer.

2) the different state of the surface of the soil with these crops. When the surface is friable, precipitation is better able to penetrate to the deep layers of the soil profile, and this reduces evaporation losses. Careful tilling between the corn rows kept the soil in a friable state until the end of July. Moisture losses from surface evaporation were therefore less from the corn field than from the compacted surface of the rye field, and precipitation wetted the soil to a considerably greater depth in the corn field.

The uptake of soil moisture by plants is determined by its availability (5, 6, 8). To determine the effect of weather conditions and the nature of the cultivated crops on the condition of the soil moisture and its availability to plants, we shall compare Rode's categories of soil moisture (8) with the moisture content of the separate layers in 1956 and 1957.

The curves in A of Figure 1 show that from the end of May until July 11, 1956, the moisture in the plowed layer (0 cm-20 cm) beneath winter rye was only available to the plants with difficulty (SA). The same condition was only observed in this layer in the corn field in the last ten days of June. From the middle of July until the corn was harvested on September 9, the availability of the soil moisture to the plants was high.

In the dry year of 1957 (B, Fig. 1), moisture was only available with difficulty to both corn and winter rye in the plowed layer (0 cm-20 cm) from May 10 through August 10. The roots of the winter rye in this layer were in a worse condition for moisture supply than the corn roots, since the moisture content in the soil of the rye field decreased practically to the permanent wilting moisture level (WM) while it remained within the range of moderate availability (MA) in the corn field.

Moisture content in the 20 cm-50 cm soil layer in the wet year of 1956 varied between moderate and easy availability (EA) for the plants; it decreased continually for the winter rye from May 19 to July 11 and was only available with difficulty towards the end of this period. In the dry year of 1957 the moisture content of this soil layer was in the available-with-difficulty range from the end of May until the rye was harvested, and in the moderately available range for corn throughout the whole growing season.

In both years the moisture content in the 50 cm-100 cm soil layer was in the range of moderate availability in the corn field and lowered to available-with-difficulty in the rye field. It should be noted that the moisture content of this layer was almost unaltered for a long time in the rye field in 1956 and for both crops in 1957. It was considerably less than field moisture capacity in both years, especially for the rye field.

In explaining this, we should remember that soil moisture was in a suspended state in the plot used for the observations and moved mainly as liquid water. After the moisture content in the soil has reached a certain level, its movements through the profile in the liquid state is halted (1, 2). At this point the moisture of broken capillaries (1), which is approximately 70% of field moisture capacity for clay loams (8).

The fact that the moisture content of the 50 cm-100 cm layer remained practically constant for a long time, as mentioned previously, may have been due largely to correspondence to this value either of field moisture capacity or of the moisture of broken capillaries. However, our information shows that there can be other reasons. It can be seen from Table 1 that field moisture capacity for the 50 cm-100 cm layer is 180.4 mm and that the moisture of broken capillaries is 142.0 mm. In the dry year of 1957, water content in the 50 cm-100 cm layer in the corn field varied between 168 mm and 171 mm between May 20 and July 30. It could, therefore, seem quite probable that the constant moisture in the 50 cm-100 cm layer was due to its relationship to field moisture capacity, since the two values are close. This would be incorrect. In view of the great dryness of the summer of 1957, one would have expected migration of liquid water from the lower to the upper soil layers. This process, which was not, in fact, observed, should have continued until the moisture content of the lower layers fell to MBC.

Owing to the high temperature and very slight precipitation in 1957, the upper layer (0 cm-20 cm) of the soil dried out rapidly, and its moisture content for the considerable period when the moisture content of the 50 cm-100 cm layer was constant was at or below MBC.

It can be concluded, therefore, that migration of moisture from the lower layers of the soil to the upper layers as liquid will cease when the moisture of the upper layer has fallen to MBC under certain weather and soil conditions. An amount of water considerably in excess of MBC will be retained in the lower layers. The more intensively the upper soil layer dries out, the more the moisture that will remain in the lower layers. This is confirmed by the fact that the moisture content of the 50 cm-100 cm layer was higher in the dry year of 1957 than in the wet year of 1956 in the corn field before the end of July.

Even after the moisture in the upper layer (0 cm-20 cm) has reached MBC, the amount of moisture in the lower layers (50 cm-100 cm) may be reduced. This was found in the soil of the rye field in both years. The reduction in moisture was due to its uptake by the plant roots in the 50 cm-100 cm layer, and not to movement as liquid into the upper layers.

The values in Table 4 and the curves A and B of Figures indicate that the reduction in the moisture content in the 50 cm-100 cm layer in the rye field from assimilation by plant roots proceeds no further than an absolute identical limit for both years. It may be concluded, therefore, that below this level the moisture in the soil is unavailable to the plants, although it is greatly above the wilting moisture. This moisture is unavailable to the plants for the following reasons: 1) when soil moisture falls to the given level there is a great reduction in its availability because its content in the soil is then at MBC (142.0 mm) for the given layer; 2) there is little invasion of this soil layer by hair roots owing to the fine texture of the soil.

Constant moisture in the 50 cm-100 cm layer is established more rapidly in the corn field in a dry year than in the rye field and remains at a higher level. It may therefore be concluded that the moisture in this layer is unavailable to the corn in a dry year, since the greater part of its roots, as already mentioned, are in the upper layers (0 cm-30 cm). The corn therefore suffered greatly from lack of moisture in 1957 and the green mass yield was only 119.8 cntr/ha as against 527 cntr/ha in the wet year of 1956, whereas the rye yield was 8.2 and 8.0 cntr/ha respectively.[3]

Conclusions

1. The moisture content of a gray forest soil is greatly affected by the nature of the cultivated crop as well as by the amount of precipitation.

2. Migration of liquid water from the lower layers to the upper layers of the soil is a typical feature of fine-textured gray forest soils in a dry year. This makes it difficult for the plants to utilize the moisture in the deep soil layers.

3. Spring and summer precipitation does not normally penetrate to the deep soil layers (below 20 cm) in winter rye fields and is expended in plant transpiration and in surface evaporation. The amount of atmospheric precipitation to penetrate the deep soil layers in a wet year is considerably greater in corn fields than in winter rye fields.

4. Soil sown to corn makes more effective and economic use of the moisture of spring and summer precipitation than does soil sown to winter rye.

5. In dry years corn roots draw moisture only from the upper half meter layer of a gray forest soil.

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[3] I. G. Abyzov and V. G. Minibayev assisted with the records of field moisture capacity.

CARBONATE SALINIZATION ($CaCO_3$ AND $MgCO_3$) AND ITS DISTRIBUTION IN THE SOILS OF THE ZERAVSHAN VALLEY

P. UZAKOV, V. V. Kuybyshev Agricultural Institute, Samarkand

It has been established in the last few years that extensive areas of the hydromorphic soils in the middle reaches of the Zeravshan valley have undergone carbonate salinization. New carbonate formations are clearly apparent at various depths (between 0.3 m and 1.5 m) as whitish horizons, microconcretions, large concretions, and hardpans known as "shokhi".

Shortly after Kuguchkov first described the carbonate type of salt accumulations (10, 11) he discovered magnesium carbonate salinization in the Zeravshan valley. The accumulation of carbonates has also been described by Kovda (8).

It has emerged from determination of the composition of soil carbonates by acetic acid that calcium and magnesium salts are largely differentiated in the soil profile during salt accumulation: large amounts of calcium salts accumulate in the lower layers, and magnesium salts accumulate in the surface layers in large amounts (Table 1).

Kuguchkov (12) and Saidov (16) have established that an increased amount of magnesium carbonate in the soil has a distinctly toxic effect on cotton and greatly reduces its yield (5-7 cntr/ha).

Nevertheless, many investigators and practical workers still believe that even a high content of calcium and magnesium carbonates in the soil has no harmful effect on crops. Yegorov (19), for example, suggests that the quality and quantity of the cotton harvest are not normally affected. Many others consider that the carbonate salts of bivalent metals are not harmful to plants in meadow-bog carbonate solonchaks. Kovda (8) indicates that the greater part of the magnesium carbonate comes out of solution with calcium carbonate in the lower soil horizons and forms dolomite, which has no toxic effect on plants, since it is only slightly water-soluble.

Feofarova (5) has established that calcium carbonates are present as coarse-grained pelitomorphic and powdery calcite in the concretions and hardpans of the meadow and meadow-bog soils of the Zeravshan valley; powdery calcite cements the soil mass and makes it extremely hard. Little dolomite (0.13%) was found in these new formations.

Kuguchkov's experiments (12) established that the solubility of calcium carbonate is adversely affected by an increase in the magnesium carbonate content in the solid phase of sierozem soils. This feature is of extreme importance in the carbonate salinization and desalinization of these soils.

Later research by Agisheva (1) and myself has not confirmed the theory that dolomite is formed during carbonate salinization. Analytical data demonstrate that considerably more magnesium carbonate always passes into solution in carbonate water extracts of salinized soils.

The presence of magnesium carbonate was established by Kuguchkov (14) by leachings salinized soils in glass tubes. Since the forms of the magnesium and calcium carbonates are of great importance for soil fertility, I determined them by thermal and mineralogical analysis.

Calcite is dissociated according to equation $CaCO_3 = CaO + CO_2$ at temperatures of between 800° C and 1029° C (Curve a of Fig. 1).

Dolomite is dissociated in two stages. The first endothermic effect is observed, according to L. G. Berg, at a temperature of 730° C and is due to decomposition of the two carbonates into $CaCO_3$ and $MgCO_3$ accompanied by gradual dissociation of the $MgCO_3$. The second effect — at a temperature of 900° C — is connected with the dissociation of calcium carbonate (Curve b of Fig. 1).

Magnesite is dissociated considerably earlier than calcite according to equation $MgCO_3 = MgO + CO_2$. The temperature range for magnesite dissociation is between 570° C and 600° C. The presence of magnesite and not dolomite in the soil is indicated by the fact that when samples of meadow and meadow-bog soils with a high magnesium carbonate content are subjected to thermal analysis, dissociation occurs at 570° C (Curve c of Fig. 1).

After removal of the calcite and magnesite by treatment with 20% HCL at a low temperature (so that the dolomite would not dissolve) by Belyankin's method (5), the same soil samples were subjected to thermal analysis in the soil mineralogy laboratory at the V. V. Dokuchayev Soil Institute. On the resultant thermogram (Curve d of Fig. 1), there is a low endothermic

Table 1

Composition of soil carbonates in meadow soil of the "Moskva" kolkhoz, Dzhambai rayon.[a] Profile 3

Depth, cm	Ca^{++}	$CaCO_3$	Mg^{++}	$MgCO_3$	Total $CaCO_3$ and $MgCO_3$	As a % of the total meq	
						$CaCO_3$	$MgCO_3$
0—18	$\frac{5,0}{249}$	$\frac{12,49}{249}$	$\frac{3,17}{260,0}$	$\frac{11,10}{263}$	$\frac{23,59}{512}$	48,6	51,4
18—38	$\frac{7,9}{394}$	$\frac{19,73}{394}$	$\frac{7,62}{627,0}$	$\frac{26,42}{627}$	$\frac{46,15}{1021}$	38,5	61,5
38—60	$\frac{11,5}{574}$	$\frac{28,72}{574}$	$\frac{8,09}{665,0}$	$\frac{28,05}{665}$	$\frac{56,77}{1239}$	46,3	53,7
60—90 (shokh)	$\frac{25,5}{1272}$	$\frac{63,68}{1272}$	$\frac{3,78}{311,0}$	$\frac{13,10}{311,0}$	$\frac{76,78}{1583}$	80,3	19,7
90 and below	$\frac{30,6}{1527}$	$\frac{76,41}{1527}$	$\frac{2,16}{177,0}$	$\frac{7,49}{177}$	$\frac{83,9}{1704}$	89,0	11,0

[a] In percentages in the numerator and in meq per 100 g of air-dry soil in the denominator.

Note: Comma represents decimal point.

reaction (140° C) associated with the elimination of adsorbed water and an exothermic effect (between 300° C and 600° C) from combustion of organic matter. The loss of weight is 50 mg. There is no loss of weight above 600° C; the endothermic effect at 780° C is therefore associated with lattice reconstruction of a clay mineral, and the exothermic effect at 800° C is associated with the formation of new crystalline phases. The small extended peak between 420° C and 500° C is clearly associated with the presence of hydroxyl groups in the lattice of a clay mineral. The heating curve in no way reflects the presence of dolomite.

Some of the soil samples treated with 20% HCL at low temperature were subjected to mineralogical analysis (carried out by I. I. Feofarova) which revealed that secondary dolomite was completely absent and that there was very little primary dolomite (0.002%-0.014%.)

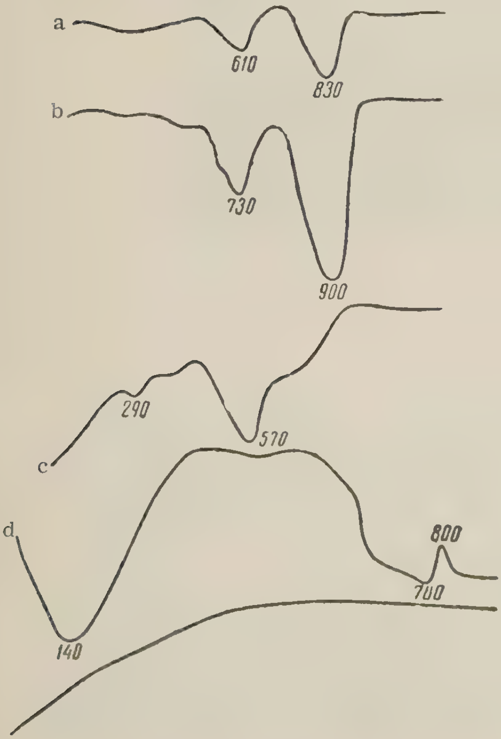

Fig. 1. - Thermograms of Ca and Mg carbonates. a - calcite (from "The Physical Chemistry of Silicates" by A.I. Avgustinnik, 1947); b - dolomite (N. M. Strakhov. Tr. In-ta. geologich. nauk, No. 124, 1951); c - magnesite (obtained by the author); d - thermogram of soil sample after removal of $CaCO_3$ and $MgCO_3$.

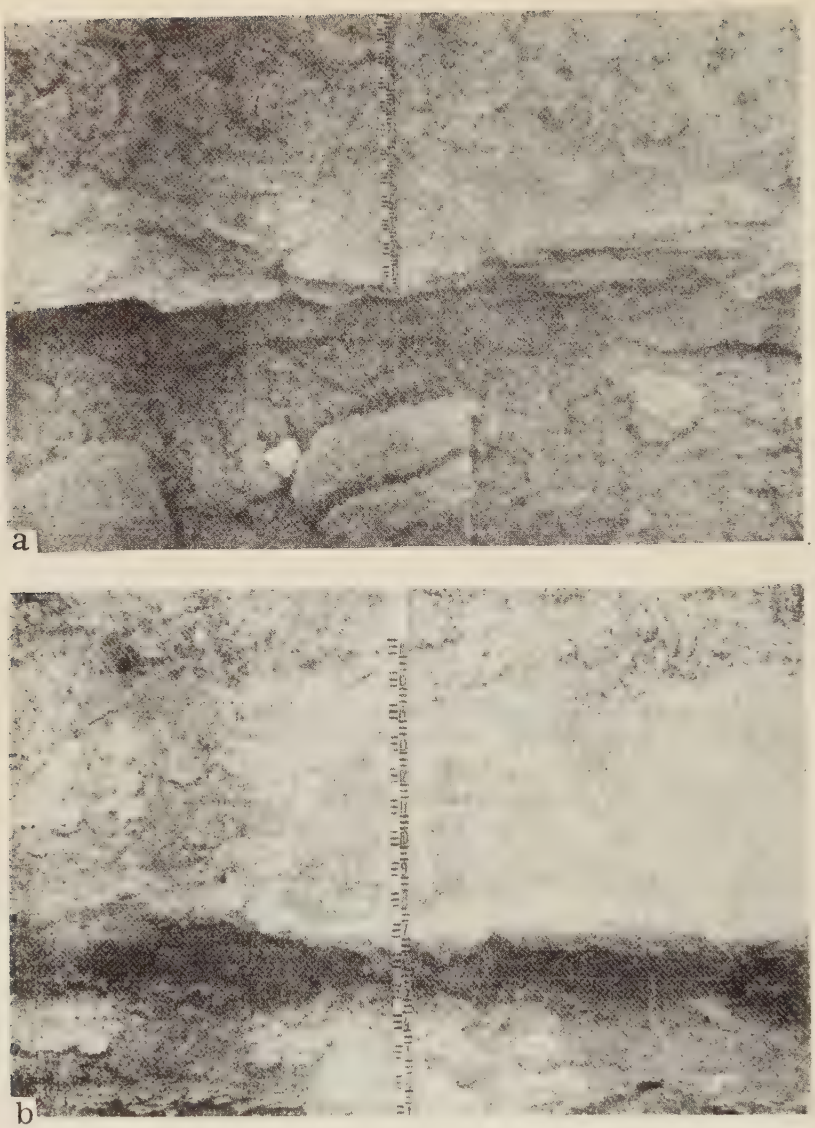

Fig. 2. - Soil with hardpan ("shokh") (A); Soil with two parallel hardpans (B).

Thus, our research has established that the magnesium carbonate is not incorporated in a dolomite molecule but occurs in the soil as magnesite, which is far more readily soluble in water saturated with carbon dioxide and may therefore have a toxic effect on cotton and other crops.

Soils with a double parallel hardpans are often found under natural conditions. Their formation is due to the fact that the groundwaters were very close to the surface, at a depth of approximately 50 cm-80 cm, in the distant past and produced the first upper hardpan on evaporation. As the river base level fell, the groundwaters sank to a depth of 120 cm-140 cm, at which time the second hard layer began to be formed parallel to the first. Its formation is still continuing (a and b of Fig. 2). Meadow vegetation was also apparently involved in the formation of the "shokh" layers. Carbonate salts are also precipitated from solution when soil and subsoil water is used in transpiration.

Our research has shown that the presence of calcium and magnesium in the adsorption complex is a typical feature of the meadow and meadow-bog soils that are widely distributed in the middle reaches of the Zeravshan. In many cases there is more adsorbed magnesium than calcium (3, 9).

Kudrin and Rozanov (9) and Bratcheva (3) are of the opinion that adsorption complexes with increased magnesium content were formed in the distant past by salinization of the soils by magnesium sulphates. In the desalinization of soils of this type, calcium is displaced from the adsorption soil complex and replaced by magnesium. Gypsum should form when calcium is displaced in such soils.

However, it is clear from topographic position and hydrogeological conditions that the hydromorphic soils of the middle reaches of the Zeravshan, especially in the east, were never subjected to sulphate salinization. These soils contain no gypsum and very small amounts of easily-soluble salts.

According to our research, an adsorption soil complex with a high content of exchangeable magnesium is formed on the evaporation of bicarbonate groundwaters. As already noted it is mainly the carbonate salts of calcium that are precipitated in the lower soil horizons when bicarbonate groundwaters move to the evaporation surface. Magnesium bicarbonates may ascend via the capillaries to the very surface, in which case magnesium cations will be more plentiful than calcium cations in soil solutions in the upper horizons. The magnesium cations will enter the adsorption soil complex by displacing adsorbed calcium. This is why there is more magnesium than calcium in the adsorption soil complex of some meadow and meadow-bog soils in the middle reaches of the Zeravshan valley. It can be seen from Table 2 (determinations by Shmuk's method) that adsorbed magnesium accounts for 24.01-31.33 meq per 100 g of air-dry soil in the upper horizons of high humus meadow and meadow-bog soils (i.e., 75%-76% of the total of cations). There is extremely little exchangeable sodium and potassium (0.72 meq-0.91 meq).

The effect of adsorbed magnesium on the physico-chemical properties of soil has been dealt with by Gedroyts (6), Prasolov and Antipov-Karatayev (15) Usov (18), Breshkovskiy (4), Kudrin and Rozanov (9), Bratcheva (3) Grishin (6) Shavrygin (17), and others. According to references in the literature, adsorbed magnesium has the effects of increasing the dispersion of soils, reducing the level of micro-aggregation and porosity, producing considerable compaction in the dry state, increasing cohesion, etc. The effect of magnesium on the physico-chemical properties of soil is to some extent similar to that of sodium.

The micro-vegetational research of Mamayeva has established that magnesium humates are toxic to the root systems of barley seedlings. In soils with a variable ratio between exchangeable calcium and magnesium, the toxicity limit is reached when the magnesium accounts for 80% of the exchangeable cations; the negative effect of exchangeable magnesium begins to be apparent when its content is approximately 40%.

Our field research has shown that soils with an enhanced content of magnesium carbonate and adsorbed magnesium are highly compact; they have takyr-like block disintegration which is cloddy, prismatic or columnar in the surface horizons, and which separates with a relatively smooth surface that is difficult to disrupt.

Thus, soils of this type have a clearly defined solonetz structure and are extremely difficult to work. They normally have a high alkaline reaction (pH 8.6 and above).

Table 2

Composition of adsorbed cations in the soils studied

Depth, cm	In meq per 100 g of air-dry soil				As a % of the total of cations		
	Ca^{++}	Mg^{++}	$Na^{+}+K^{+}$	Total	Ca^{+}	Mg^{+}	$Na^{+}+K^{+}$
Irrigated meadow soil. "Lenin-Yuly" kolkhoz, Komsomol'sk rayon. Profile 15							
0—20	14,17	18,91	0,58	33,66	42,09	56,19	1,72
20—30	10,78	12,75	0,49	23,97	44,97	52,99	2,04
40—60	5,59	4.93	0,17	10,69	52,29	46,12	1,59
60—80	6,78	5,84	0,19	12,81	52,92	45,60	1,48
90—110	5,99	2,22	0,09	8,29	72,25	26,67	1,08
120—140	3,99	2,88	Not det'd	6.87	58.07	41,93	
Meadow soil. "Moskva" kolkhoz, Dzhambai rayon. Profile 3							
0—18	15.17	21,55	0,91	37,63	40.31	57,28	2,41
18—38	9,38	31,33	0.72	41,43	22.64	75,03	1,73
38—60	6,39	24.01	0,95	31,35	20.38	76,59	3,03
60—90	13.17	8,88	0,48	22,53	58.45	39,42	2,13
90 and below	9,58	1,23	0,18	10,99	88,08	11,29	1,63

Note: Comma represents decimal point.

The Zeravshan soils under consideration have many of the features of solonetzes when there is enhanced magnesium content in the adsorption complex.

Prolonged irrigation of salinization carbonate soils leads to their gradual desalinization. This naturally changes the distribution pattern of calcium and magnesium carbonate salts in them. A large part of the magnesium carbonate is leached from the upper soil layers and accumulates in the lower layers. Such soils are widely distributed on cotton and rice fields that have long been irrigated (Table 3).

Table 3

Composition of soil carbonates

Depth, cm	As a % of 100 g of air-dry soil				Total $CaCO_3$ and $MgCO_3$	As a % of total meq	
	Ca	$CaCO_3$	Mg	$MgCO_3$		$CaCO_3$	$MgCO_3$
Meadow soil. "Pay-Aryk" sovkhoz. Profile 1							
0—25	17,9 893	44,75 894	1,28 105	4,48 106	49,23 1000	89,4	10,6
25—40	18,6 898	45,00 899	1,59 130	5,57 131	50,57 1030	87,2	12,8
55—70	20,9 1038	53,25 1033	4,21 346	14,73 347	67,98 1380	74,7	25,3
80—110	28,7 1432	71,75 1432	5,49 451	19,21 453	90,96 1885	75,9	24,1
Meadow-bog soil. "Dzhambai" sovkhoz named after Kirov							
0—20	15,3 763	38,25 763	1,58 130	5,53 131	43,78 894	85,3	14,7
20—40	18.0 898	45,00 899	3,16 287	11,06 289	56,06 1188	75,6	24,4
40—60	21,60 1077	54,00 1077	3.66 301	12,81 304	66.81 1381	78,0	22,0
Meadow soil. "Pay-Aryk" sovkhoz. Profile 4							
0—25	13,0 649	32,50 649	2,07 170	7,25 172	39,75 821	79,05	20,95
30—45	12.4 619	31,00 619	2,38 196	8,33 199	39.33 818	75,67	24,33
50—65	20,5 1024	51,25 1024	6,71 552	23,49 558	74.74 1582	64,72	35,28
65 and below	24,6 1228	61,50 1229	6.10 502	21,35 506	82,85 1735	70,83	29,17

Note: Comma represents decimal point.

Table 4

Composition of adsorbed cations in irrigated meadow soil "Pay-Aryk" sovkhoz. Profile 4.

Depth, cm	As a % and meq per 100 g of air-dry soil			As a % of total meq	
	Ca^{++}	Mg^{++}	Ca^{++} $+Mg^{++}$	Ca^{++}	Mg^{++}
0—25	$\frac{0,240}{12,00}$	$\frac{0,270}{22,20}$	$\frac{0,510}{34,20}$	35,08	64,92
30—45	$\frac{0,160}{8,00}$	$\frac{0,147}{12,09}$	$\frac{0,307}{20,09}$	39,82	60,18
50—65	$\frac{0,120}{6,00}$	$\frac{0,073}{6,00}$	$\frac{0,193}{12,00}$	50,00	50,00
65 and below	$\frac{0,080}{4,00}$	$\frac{0,049}{4,03}$	$\frac{0,129}{8,03}$	49,81	50,19

Note: Comma represents decimal point.

Our studies show that in desalinization of the soils the composition of the adsorption soil complex is little changed initially, and the replacement of adsorbed magnesium by calcium lags considerably behind the desalinization processes.

There are also soils in which magnesium carbonate has been leached from the soil profile but in which magnesium is still more plentiful than calcium in the adsorption soil complex (Table 4). Such soils are of lower fertility.

We have examined areas of calcium and magnesium carbonate salinization in the Komsonol'sk, Samarkand, Bulungursk, Dzhambai, Pay-Aryk, Ak-Dar'insk and other Oblasts' of the Zeravshan rayon. These areas are on the alluvial plain and especially in the watercourse valleys of the former Zeravshan.

Soils with magnesium carbonate salinization and a high content of adsorbed magnesium are of lower fertility. Their cotton yield is 8-10 cntr/ha.

Conclusions

1. Hydromorphic irrigated meadow and meadow-bog soils have undergone calcium and magnesium carbonate salinization, which has led to the formation of compact cemented layers known as "shokh" in the lower layers. Large quantities of magnesium carbonate have accumulated in the upper layers.

2. The carbonate salts of calcium are represented by the mineral calcites and the salts of magnesium by magnesite. The form of the magnesium carbonate was established by thermal and mineralogical analysis.

3. In soils with magnesium and calcium carbonate salinization, the adsorption soil complex, especially in the upper layers, is saturated mainly with magnesium cations and partly with calcium cations. It contains very little sodium and potassium cations.

4. Research has revealed a direct connection between magnesium carbonate salinization and the formation of an adsorption soil complex in which the magnesium cation predominates. The participation of easily soluble salts in this process is excluded.

5. In desalinization processes, magnesium carbonates are leached to a considerable depth in the soil or may be removed from the soil profile by prolonged irrigation, whereas adsorbed magnesium is firmly retained in the surface layers for a longer period.

6. Soils that contain an increased amount of exchangeable magnesium in the adsorption complex are similar to solonetzes in their morphological and chemical properties.

7. It has been established that there are solonchak-like soils with a high content of magnesium carbonate in their lower layers and solonetzic soils with an enhanced content of exchangeable magnesium in the hydromorphic soils of the Zeravshan valley. These soils of magnesium and calcium carbonate salinization are genetically closely related and of low fertility.

8. The fertility of soils with magnesium carbonate salinization can be increased by deep plowing without moldboard (45 cm-50 cm) and the application of organo-mineral fertilizers if the "shohk" is near the surface.

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SOILS OF THE HILLY TERRITORIES OF NORTHERN VIET-NAM

V. M. FRIDLAND, V. V. Dokuchayev Soil Institute

The relief of Northern Viet-nam is clearly divided into plains (mainly lowland plains), hilly country, and mountains (8).

Various alluvial soils predominate in the plains composed of young fluvial deposits, but bog soils are also quite common and there are salinized soils in the maritime districts.

I have given a brief description of the mountain district soils, the geography of which is primarily determined by vertical zoning in a previous paper (6).

The present paper is devoted to the soils of the hilly territory, where the basic zonal soils of this humid tropical land predominate.

Values for the climatic conditions in the hilly territory are given in Table 1. Since the mean temperature of the coldest month is 14.7° C, even in the extreme north of the foothills (Fu-Ho) natural flora and crops can grow all the year round.

The annual pattern of precipitation and evaporation establishes two main seasons, in one of which precipitation exceeds evaporation and in the other of which evaporation exceeds precipitation. In accordance with the district, the number of months in which evaporation exceeds precipitation varies between 2-3 and 4-5. Even in the driest parts of the hilly territory (Fu-Kui) there is no month in which evaporation exceeds precipitation by more than 40 mm and during the rains precipitation exceeds evaporation by 100 mm – 200 mm and more a month. The soils therefore remain quite moist throughout the year. During three years of observations in Fu-Kui, which, as already mentioned, contains the driest areas of the hill country, it was found that soil moisture only falls to the wilting moisture for very short periods and then not every year.

Owing to these climatic conditions humid tropical forest developed extensively in the hilly territory of North Vietnam, but the primary forests have now been almost entirely replaced by various secondary types of forest, shrub thickets, and cultivated crops.

The parent materials, which are most diverse, are the weathering products of shales, gneisses, granites, basalts, volcanic tuffs, marmorized limestones, carbonate sandstones, and other rocks.

In relief the hilly territory is mainly an ancient pre-Quaternary peneplain that developed under undisturbed tectonic conditions. After the active movements of the Alpine mountain building a considerable part of the territory of Northern Viet-Nam was upraised and became mountainous, while another part was lowered and subsequently covered by deltaic deposits and converted into plain. Hilly topography was only retained in the tectonically undisturbed conditions at the contact between the zones of uplift and subsidance; its development here followed the same pattern as before the Alpine movement. In other parts of the hilly territory, however, the relief is differently conditioned; here the Alpine movements did not produce upheavals and subsidances but led to the formation of fractures associated with outpourings of basic lavas and a resulting smoothly undulating relief that is clearly distinguishable from the more dissected relief of the greater part of the hilly territory.

The hilly relief favors the development of well drained soils, but soils that developed under conditions of poor drainage with ground water close to the surface are also quite common. The extensive development of compact lateritic soil horizons associated with poorly drained soils has been described in greater detail in other publications (9, 10) and only soils formed without the influence of ground waters will here be considered.

Three groups of soils formed without the influence of ground waters can be clearly distinguished in the hilly territory:

1) red and yellow soils often forming blends of these tones, with a cloddy structure in the upper horizons and the structure of the parent material in the middle and lower parts of the profile;

2) dark red uniformly colored friable soils, almost cinnamon-brown in the upper part, with excellent granular structure throughout the profile;

3) black soils paling to a slightly reddish tinge below; the structure of these soils is stable when the texture is fine and usually unstable when the texture is coarse.

Table 1

Climatic conditions of the hilly territory of Northern Viet-Nam

Climatic features	Month												Year
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Fu-Ho 21° 27' N. 105° 15' E, altitude 25 m													
Mean temperature °C	14,7	17,0	18,9	23,0	27,0	28,3	28,0	27,9	26,7	24,0	21,0	17,8	22,9
Mean relative humidity,%	88,8	88,8	89,2	89,6	86,3	85,7	86,9	88,6	88,6	85,1	85,8	88,1	87,5
Precipitation, mm	31	49	53	97	106	228	333	334	237	128	36	35	1747
Evaporation, mm	33	35	38	45	68	80	66	68	55	65	55	37	645
Fu-Kui, 9° 32' N, 104° 44' E, Altitude 75 m													
Mean temperature °C	17,3	18,3	20,4	25,1	28,1	29,1	28,0	28,4	26,8	23,8	21,1	19,3	23,9
Mean relative humidity,%	85,5	86,1	85,7	83,6	81,4	79,4	82,8	85,4	87,4	85,2	86,4	86,4	84,6
Precipitation, mm	10	31	26	61	163	106	250	164	333	152	54	26	1376
Evaporation, mm	50	47	53	74	93	103	87	77	63	63	55	48	813

Note: Comma represents decimal point.

In view of the uniform bioclimatic conditions in the territory the differences in the soils may be thought to be due to the parent materials. This can, in fact, be seen quite clearly. The soils of the first group develop on shales, gneisses, granites, and rhyolites; those of the second group on basalts, porphyrites, and marmorized limestones; and those of the third group exclusively on basic volcanic tuffs and lavas.

None of these groups are in any sense uniform. The soils in a group differ in humus content, texture, and other attributes. Since treatment of these internal distinctions would require examination of a great deal of material each of the groups will here be described from a single profile with the object of revealing the basic features of each group. The following description is an example of the first group.

Profile 442. En-Bai province, Chan-En district near the settlement of Dat-Den. A pass through a hilly ridge with altitudes of 75 m-80 m. Freshly revealed by the construction of a road. Remains of humid tropical forest and overgrown with grass.

0 cm-25 cm	Reddish-brown, clay, fine granular structure, moist, many roots. Gradual transition.
25 cm-95 cm	Brownish-red, clay, cloddy unstable structure, moist roots. Gradual transition.
95 cm-450 cm	Brownish-red, clay, retaining the morphological appearance of shale (apparent layering and differences in the structure of the layers). Gradual transition.
450 cm-650 cm	A mass of weathering shale of varying color (yellow, rust, brown, violet). Easily cut with a knife. gradual transition.
650 cm-1000 cm	Reddish-brown, more gently weathering shale, easily cut with a knife. Gradual transition.
1000 cm-1400 cm	Weathering shale, greenish-yellow and brown. Weathering less advanced than in the superjacent horizons, cannot be cut with a knife, breaks into typical shale fragments.

The second group is represented by a profile developed on a thick weathering crust (more than 15 m) of andesite-basalts.

Profile 17. Nge-Dan province, Tai-Hien State Farm. Gently undulating surface. composed of basalts. Thick secondary evergreen forests without grass cover. A few dry leaves on the surface of the soil.

0 cm-45 cm	Reddish-cinnamon-brown, very friable, cloddy-granular stable structure. fresh, tree roots. Gradual transition.

45 cm-100 cm	Reddish-cinnamon-brown, lighter and somewhat less friable; stable structural units; fresh; noticeably fewer roots. gradual transition.
100 cm-250 cm	Cinnamon-brown-red, granular-cloddy, moist, some plasticity, structural units less stable; hard pisolitic and ferro-manganic concretions. Gradual transition.
250 cm-380 cm	Brown, cloddy, damp, plastic, contains a considerable quantity of stable pisolitic concretions up to 3 mm-4 mm in diameter especially between 300 cm and 350 cm. Gradual transition.
380 cm-450 cm	Cinnamon-brown-red, granular, cloddy, damp, plastic, few concretions; ferro-manganic concretions.

The soil representing the third group is described from a point some kilometers from the previous profile. It is developed on volcanic tuff.

Profile 74. Nge-An province, Ne-Dan district, Tai Hien State Farm. 5 km to the south of Central Buildings of the "Tai-Hien" State Farm. A chain of volcanic uplands (altitude up to 173 m). Tuff outcrops and pumice fragments on the slope of a high hill. The whole upland is thickly covered with grasses up to 1 m high with occasional stunted palms and a few isolated trees of pod-bearing varieties.

0 cm-20 cm	Black, clay, structured, friable, thickly penetrated by roots, moist. Gradual transition.
20 cm-55 cm	Brownish-black, moist, cloddy, compact, plastic, occasional rounded pumice fragments up to 5 cm-7 cm in diameter; far fewer roots. Gradual transition.

Table 2

Particle size analysis of soils of the hilly territory of Northern Viet-Nam, %

Profile No.	Depth, cm	Hygroscopic moisture, %	Losses on treatment with HCl	Diameter of particles, mm					
				1,0—0,25	0,25—0,05	0,05—0,01	0,01—0,005	0,005—0,001	<0,001
442	0—10	2,80	1,1	2,7	12,3	10,1	7,0	22,0	44,3
	10—20	2,64	0,9	2,2	13,3	11,3	2,8	19,8	49,7
	30—40	2,58	0,6	1,9	12,2	9,4	7,5	19,9	48,5
	70—80	2,45	0,4	2,1	14,6	8,2	3,9	18,4	52,4
	170—180	2,33	0,7	2,1	13,0	8,6	4,6	17,5	53,5
	350—360	1,97	0,7	4,9	18,1	11,8	7,2	17,4	39,9
	570—580	2,00	0,5	8,0	16,8	15,3	8,3	17,6	33,5
	810—820	2,17	0,4	2,5	13,9	21,9	11,2	24,6	25,5
	1190—1200	2,90	0,5	15,7	32,8	20,8	7,6	16,3	6,3
17	0—10	3,90	2,1	1,6	1,4	12,7	7,8	10,6	65,9
	10—20	3,88	1,7	1,3	5,6	10,4	7,3	9,2	64,5
	20—30	3,85	1,3	0,6	9,8	8,4	4,8	8,3	66,3
	40—50	3,86	1,2	0,6	6,6	7,6	5,6	6,8	72,8
	60—70	3,83	1,2	0,6	7,7	8,4	5,2	5,2	71,6
	80—90	3,83	1,1	0,7	8,5	8,4	4,0	6,4	71,6
	100—120	3,55	1,1	1,1	3,9	10,3	5,3	6,4	72,9
	200—210	3,63	0,7	1,1	3,2	11,8	3,6	7,5	72,8
	300—320	5,04	0,6	18,7	22,1	12,1	3,3	5,4	38,4
	400—420	4,98	0,6	17,0	16,4	13,5	4,4	6,1	42,0
74	0—10	6,84	3,9	1,8	9,9	22,6	16,2	20,6	25,0
	10—20	6,42	3,9	1,3	8,8	19,5	14,2	22,0	30,3
	25—35	7,26	3,0	1,1	4,5	18,1	12,6	14,2	46,5
	40—50	7,60	3,3	1,5	10,6	13,2	10,9	12,7	47,8
	55—65	7,85	3,0	5,0	14,4	6,8	13,6	10,8	46,6
	80—90	7,75	5,2	4,7	11,6	5,5	10,0	14,0	48,0

Note: Comma represents decimal point.

55 cm-90 cm	Similar to the previous level, but moisture and with more pumice fragments; somewhat lighter and with a more distinct cinnamon-brownish tinge; no roots.

Each of these profiles had distinct structural features. Profile 74 is continually black (unvariegated) and has a stable structure with large units. Profile 17, like the preceding profile, is of uniform coloration but is cinnamon-brownish red and not black; it is only dark brown in the horizon containing concretions. The whole profile is well structured to a depth considerably below the root zone and the units are noticeably smaller than in profile 74. Profile 442 has very distinctive features. Throughout its thickness of almost 15 m it has the typical variegated coloring and composition of the undisturbed shale bed from which the soil was formed. Thus its structure shows clearly that chemical weathering preceded physical weathering and that the rock, in its original undisturbed bedding, altered its mineralogical and chemical composition. Only the upper 95 cm layer has acquired structure and homogeneity under the direct influence of root systems. It should be emphasized that homogeneity and structuring in soils formed on the eluvium of shales, gneisses, granites, and other rocks (except for igneous basic rocks) are always associated with the action of tree and herbaceous root systems; outside the sphere of influence of the root systems the weathering products in situ always retain the structure of the initial rocks. The soils also differ in texture (Table 2). The soil of profile 17 has the very fine clay loam texture. It is only in the lower horizons in which there are concretions that the texture becomes noticeably coarser due to the formation of a considerable quantity of small concretions (0. 05 mm-1 mm in diameter) that are clearly visible under a binocular microscope.

The soil from profile 442 has a coarser texture and is a silty-clay clay. It differs fundamentally from profile 17 in that the amount of silt and even sand particles becomes considerable. There are noticably fewer clay particles in the lower, less weathered part of the profile which is rich in sand and large silt particles.

The soil of profile 74 also consists of clays which are mainly silty-clay and, in the upper horizons, clay-silt. The texture of all horizons is coarser than in the two previous soils.

Despite these differences it should be emphasized that all three profiles have the fine-textured clay that is generally typical of soils in the hilly territory of Northern Viet-Nam in particular and in the humid tropics in general.

The upper part of all three profiles is somewhat coarser in texture for reasons that are not fully apparent, although micro-morphological observations suggest that it is mainly due to illimerization (5).

In examining the physical properties of soils of the hilly territory (Table 3), we have used determinations that were made not on the three profiles described, in most cases, but on others with similar over-all properties.

Soils developed on basalt have much greater

Table 3

Some physical properties of the soils of the hilly territory of Northern Viet-Name.
(work conducted by A. I. Zhitkova under the supervision of S. I. Dolgov)

Profile	Depth, cm	Maximum hygroscopicity (MH)	Wilting moisture (WM)	Field moisture capacity (FMC)	Total content of available moisture	$\frac{WM}{MH}$	Porosity[a]	Field moisture capacity
		Weight, %					Volume, %	
A	0—15	21,7	30,1	37,4	,3	1,39	71,0	26,6
	15—30	22,3	31,1	38,6	,5	1,39	68,8	30,9
	30—50	22,5	30,7	37,3	6,6	1,36	66,0	32,8
B	0—5	11,5	20,6	28,4	7,8	1,79	54,1	34,9
	5—18	11,5	21,4	27,6	6,2	1,86	53,4	34,2
	18—29	12,6	33,4	30,9	7,5	1,86	49,8	42,6
F	0—13	16,9	23,1	31,6	8,5	1,37	Not det'd.	
	13—25	19,9	27,7	36,6	8,9	1,39	"	
	25—40	22,2	29,8	39,4	9,5	1,34	"	

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[a] Porosity was determined for profile 17 described previously and for a profile developed on shale similar in properties to profile 442; the structure of the samples determined was undisturbed. Field moisture capacity of samples with disturbed structure was determined in tubes.

Note: Comma represents decimal point.

Table 4

Analysis result for the soils of the hilly territory of Northern Viet-Nam

Profile No.	Depth, cm	Hygroscopic moisture, %	pH		Humus %	Nitrogen, %	C:N	Adsorbed cations											Aluminum meq/100 g of soil (Sokolov's method)	Total of adsorbed cations recal. for 100 g of coll. clay
								meq/100 g of soil						% of total						
			Water	Salt				Ca^{++}	Mg^{++}	Na^{++}	K^{+}	H^{+}	Total	Ca^{++}	Mg^{++}	Na^{++}	K^{+}	H^{+}		
442	0—10	2,80	5,6	4,5	3,92	0,280	7,8	4,87	1,22	0,12	0,04	3,08	9,33	52,3	13,1	1,2	0,4	33,0	0,84	21
	10—20	2,64	5,1	4,4	3,75	0,182	12,1	3,65	2,44	0,12	0,04	3,52	9,77	37,4	24,9	1,2	0,4	36,1	0,80	20
	30—40	2,58	5,5	4,5	3,35	0,168	11,5	2,43	1,22	0,12	0,04	3,96	7,77	31,3	15,7	1,5	0,5	51,0	0,30	16
	70—80	2,45	5,0	4,6	2,46	0,140	10,1	3,65	1,22	0,12	0,02	2,59	7,62	47,8	16,0	1,6	0,3	34,3	0,59	15
	170—180	2,39	5,0	4,7	Not det'd.		—	3,65	1,22	0,12	0,04	2,59	7,62	47,8	16,0	1,6	0,3	34,3	0,49	14
	350—360	1,97	6,0	5,3	"		—	4,87	1,22	0,24	0,05	1,87	8,25	58,7	14,8	2,8	0,6	23,1	0,09	21
	570—580	2,00	6,7	6,3	"		—	4,87	1,22	0,24	0,04	2,37	8,74	55,7	13,9	2,7	0,5	28,2	0,09	23
	810—820	2,17	6,2	6,0	"		—	3,65	1,22	0,12	0,04	2,15	7,18	51,0	17,0	1,6	0,5	29,9	Trace	28
	1190—1200	2,90	6,6	6,2	"		—	3,65	1,22	0,24	0,07	1,14	6,92	52,7	17,9	3,5	1,0	24,9	0,09	110
17	0—10	3,90	5,8	4,8	4,48	0,196	13,0	7,30	1,22	0,07	0,12	4,17	12,88	57,8	9,6	0,5	0,9	31,2	0,22	19
	10—20	3,88	5,1	4,6	2,91	0,181	9,3	Not det'd.					—	—	—	—	—	—	Not det'd.	—
	20—30	3,44	5,3	4,7	2,38	0,154	9,0	"					—	—	—	—	—	—	"	—
	40—50	3,86	5,1	4,8	1,86	0,133	8,1	2,43	2,43	0,10	0,11	2,86	7,93	30,6	1,3	1,3	36,2	36,2	0,42	11
	60—70	3,82	5,3	4,8	1,87	0,137	8,0	Not det'd.					—	—	—	—	—	—	Not det'd.	—
	80—90	3,77	5,7	4,8	1,80	0,125	8,3	"					—	—	—	—	—	—	"	—
	100—120	3,55	5,5	4,8	Not det'd.		—	3,65		0,10	0,25	1,76	5,76	63,3		1,7	4,3	30,7	0,36	8
	150—170	3,51	5,9	5,0	"		—	Not det'd.					—	—	—	—	—	—	Not det'd.	—
	200—210	3,63	5,7	5,2	"		—	"					—	—	—	—	—	—	"	—
	300—320	5,04	5,5	5,5	"		—	"					—	—	—	—	—	—	"	—
	400—420	4,98	5,6	5,3	"		—	4,87	2,66	0,21	0,42	1,77	9,93	49,0	26,8	2,1	4,2	17,9	0,21	23
74	0—10	6,48	6,4	5,2	4,57	0,308	8,4	12,17	19,47	0,50	0,73	1,35	34,22	35,6	56,8	1,4	2,1	4,1	Trace	137
	10—20	6,42	6,2	5,2	3,99	0,154	15,0	10,95	10,96	0,50	1,14	0,90	24,45	44,8	44,8	2,0	4,7	3,7	"	81
	25—35	7,26	6,4	5,1	2,12	0,168	7,3	9,74	8,52	0,50	0,12	0,91	19,79	49,2	43,1	2,5	0,6	4,6	0,42	42
	40—50	7,60	6,5	5,5	1,88	not dt.	—	9,74	12,17	0,37	0,89	1,37	24,54	39,6	49,6	1,5	3,7	5,6	0,20	51
	55—65	7,85	0,3	5,4	Not det'd.		—	8,04	12,56	Not det'd.		0,78	21,38	37,7	58,7	—	—	3,6	Not det'd.	46
	70—80	7,81	6,8	5,8	"		—	9,00	16,48	"		0,73	26,11	34,1	63,1	—	—	2,8	"	—
	80—90	7,75	6,8	5,7	"		—	7,96	26,68	"		0,68	35,32	22,6	75,5	—	—	1,9	"	73

Note: Comma represents decimal point.

porosity than soils developed on shale; this porosity is retained on saturation of the soil up to field capacity owing to the excellent aëration of soils developed on basalts. The reduced aeration of soils formed on shales is of great genetic and practical importance; it leads to gleying processes when the soils are excessively wet, especially in the rainy season. This gleying produces the mottled coloration of soils developed on shales (never found in soils developed on basalts). The difference in oxidation-reduction conditions between the soils compared is also revealed in a number of other processes that lead to important differences.

The very high value of maximum hygroscopicity and of the wilting moisture is a striking feature in analysis of the moisture properties of the soils. It is clearly due to the fine texture and to the high content of sesquioxides, which has been shown to have great effect on the moisture properties of soil (28, 17, 11).

When wilting moisture content is very high, even considerable values for field moisture capacity does not ensure a large amount of usable moisture. This leads to a paradoxical situation in which the total usable moisture is in the range of 6%-9% at 30%-40% field moisture capacity. Zonn and Li Chen-kwei have previously obtained similar values for the soils of Southern China (28).

More than 75% of the total soil moisture consists of unavailable moisture. Under such conditions luxuriant tropical forests that require large quantities of water can only develop if the soil moisture is continually replenished and if evaporation is low in the seasons when there is least precipitation.

Chemical analysis (Table 4) shows that the properties of profiles 442 and 17 differ sharply from those of profile 74. The reaction of the first two profiles is acid while that of profile 74 is practically neutral. The first two profiles have a very low exchange capacity, which when recalculated for 100 g of clay indicates that the clay fraction of these soils is similar in exchange capacity to kaolinite. Base saturation varies between 50% and 82%; calcium is the major exchangeable cation, followed by magnesium, sodium, and potassium.

Profile 74, on the other hand, is almost entirely base saturated and has a high exchange capacity; recalculation for 100 g of clay gives values close to the exchange capacity of halloysite and montmorillonite. Magnesium, which plays a large part in the adsorbed cations in profile 74, predominates in most of the horizons, followed by calcium, potassium, and sodium. There is considerably more exchangeable potassium in profile 74 than in profiles 442 and 17. This is in agreement with the Nay's conclusion (20) that herbaceous vegetation accumulates more potassium than forest vegetation under tropical conditions. Determination of exchangeable aluminum by Sokolov's method revealed relatively small quantities especially in relation to the high content of nonsilicate aluminum in the soils (to be shown below).

Thus there is a clear distinction between profile 74 and profiles 442 and 17. There are also certain differences between profiles 442 and 17 (profile 17, developed on basalt, has a slightly lower acid reaction, higher base saturation, and a higher content of exchangeable potassium than the profile developed on shale). These soils also differ in their exchange capacity for anions: the soils developed on basalts normally adsorb 15 meq-17 meq P_2O_5 per 100 g of soil and those developed on shales 10 meq-12 meq.

An examination of the distribution of exchangeable cations throughout the profile shows quite clearly the biological accumulation of exchangeable calcium. There is also an increase in the amount of exchangeable hydrogen in the upper horizons of soils developed beneath forest and the unsaturation of the adsorption complex is also increased. The basic features of biological accumulation beneath tropical forest are therefore: accumulation of exchangeable calcium and simultaneous exclusion of all other cations that are replaced both by calcium and by hydrogen (due to the influence of litter decomposition products).

Attention should be drawn to a certain instability in the content of exchangeable bases through the profile; this can be explained on the basis of the low absolute amounts, since even a slight alteration in content gives the impression of a sharp change.

The humus horizons are quite thick and there is little variation in humus content and in the carbon:nitrogen ratio between the profiles considered. On the other hand, there are very fundamental differences in the composition of the humus (Table 5). The humic acids clearly predominate in profile F (very similar to profile 74) while fulvic acids are greatly predominant in profile B (very similar to profiles 442[1] and 17). This fundamental distinction in humus composition in no way conflicts with the high base saturation, neutral reaction and considerable exchange capacity of profile 74, and the lesser base saturation, acid reaction, and low exchange capacity of profiles 442 and 17. There is no apparent explanation for the marked increase in fulvic acids in a sample from a depth of 25 cm-40 cm from profile F.

In all the samples studied the amount of matter (fats, resins, and waxes) extracted by alcohol-benzol was slight.

The distribution of the substances extracted on decalcification follows the general pattern exactly; their amount increases from more base saturated and less acid to less base saturated and more acid soils.

Interesting values were obtained in determination of available humic acids, which were very plentiful in all the samples. In samples of soils in which humic acids predominate over fulvic acids their high mobility is shown by the fact that the value for mobile humic acids is

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[1] The composition of organic matter was determined in samples B and F, the physical properties are given in Table 3.

AGRONOMY SEMINAR
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Table 5

Soils of the hilly territory of Northern Viet-Nam – composition of organic matter (analyses by N. A. Pankov and Niu Ching Wên (profile 17) directed by M. M. Kononova)

Profile	Depth, cm	Total C	C of soil after extraction	C of soil after decalcification	C of extracted substances (alcohol-benzol extract)	C of decalcinate	C of humic acids (C_{ha})			C of fulvic acids (C_{fa})			C of residue	Total	$\frac{C_{ha}}{C_{fa}}$	Mobile humic acids, %
							Fraction I	Fraction II	Total	Fraction I	Fraction II	Total				
B	0—5	1,87[a]/100	1,77/96,2	1,53/83,2	0,07/3,8	0,24/13,9	0,07/3,8	0,01/0,5	0,08/4,3	0,36/19,6	0,04/2,2	0,40/21,8	1,05[b]/57,1	1,87/100	0,20	0,21/11,3
	5—18	1,64/100	1,59/96,9	1,39/84,7	0,05/3,1	0,20/12,2	0,06/3,7	0,02/1,2	0,08/4,9	0,32/,	0,04/2,4	0,36/21,9	0,95/57,9	1,64/100	0,22	0,23/14,0
17	0—20	2,25/100	2,18/96,9	2,09/92,9	0,07/3,1	0,09/4,0	0,12/5,3	0,02/0,9	0,14/6,2	0,70/31,1	0,08/3,6	0,78/34,7	0,97/43,1	2,05/91,1	0,18	0,15/6,7
F	0—13	3,49/100	3,42/98,0	3,36/96,3	0,07/2,0	0,06/1,7	0,99/28,4	0,06/1,7	1,05/30,1	0,58/16,6	0,06/1,7	0,64/18,3	1,52/43,6	3,34/95,7	1,64	0,92/26,3
	13—25	3,08/100	3,02/98,1	2,80/91,0	0,06/1,9	0,22/7,1	0,68/22,1	0,03/1,0	0,71/23,1	0,60/19,5	0,07/2,3	0,67/21,8	1,28/41,6	2,95/95,5	1,06	0,75/24,3
	25—40	1,34/100	1,30/97,0	1,16/86,6	0,04/3,0	0,14/10,4	0,06/4,5	0,01/0,8	0,07/5,3	0,33/24,6	0,05/3,7	0,38/28,3	0,64/47,8	1,27/94,8	0,18	0,11/8,2

[a] Numerator % of soil mass, denominator – % of total mass of organic C.

[b] Residue determined by difference.

Note: Comma represents decimal point.

Table 6

Soils of the hilly territory of Northern Viet-Nam — composition of organic matter (analyses by N. A. Pankov and Niu Ching Wên (profile 17) directed by M. M. Kononova)

Determination	Profile number and depth, cm																
	442										17					74	
	0—10	10—20	30—40	70—80	170—180	350—360	570—580	810—820	1190—1200	Rock	0—10	19—50	90—120	300—320	400—420	0—10	25—35
Hygroscopic water	2,48	2,44	2,27	2,11	2,14	1,78	1,77	1,78	2,48	3,35	3,43	3,38	3,70	4,39	4,10	4,39	6,39
Losses on ignition	16,13	14,65	14,62	13,94	12,73	13,04	13,53	11,10	14,06	9,54	15.76	13,18	11,85	12,89	11,49	12,89	18,80
SiO_2 total	40,23	39,61	38,68	40,07	37,58	35,48	30,83	34,27	25,09	35,20	38.34	36,05	36,81	27,40	29,18	37,34	36,50
stable (including quartz)[a]	13,55	14,11	12,60	12,46	10,95	10,22	9,49	6,68	5,07	7,36	4,99	3,62	3,37	1,57	2,28	7,31	2,06
soluble[b]	26,68	25,50	26,08	28,61	26,63	25,26	21,34	27,59	20,02	27,84	33,35	32,43	33,38	25,83	27,10	30,03	34,44
So_3 total	0,04	0,07	0,04	0,06	0,06	Trace	Trace	0,04	Trace	0,09	0,04	0,06	0,02	0,04	0,06	0,44	0,61
P_2O_5 total	0,24	0,34	0,33	0,21	0,27	0,32	0,27	0,13	0,58	0,13	1,47	1,80	1,42	1,25	1,91	1,25	0,98
Al_2O_3 total	27,13	26,29	27,65	26,59	29,00	32,30	33,39	30,81	33,83	28,79	31,25	32,73	33,64	31,57	31,42	31,07	33,41
stable	0,29	0,22	0,65	0,28	0,47	0,80	1,22	0,23	1,82	1,33	0,50	0,13	0,42	0,03	0,23	0,66	0,24
soluble	26,84	26,07	27,00	26,31	28,53	31,50	32,17	30,58	32,01	27,46	30,75	32,60	33,22	31,54	31,29	30,41	33,17
Fe_2O_3 total	26,75	27,45	26,49	27,47	27,07	27,43	30,63	29,81	34,41	30,11	21,16	22,34	22,47	34,36	33,34	23,15	23,72
stable	0,11	0,15	Trace	0,19	0,15	0,35	0,23	0,27	1,74	1,44	0,27	0,12	0,23	0,03	0,27	0,48	0,13
soluble	26,64	27,30	26,49	27,18	26,92	27,08	30,40	29,54	32,40	28,67	20,89	22,22	22,24	34,33	33,07	22,67	23,59
R_2C_3 total	59,09	58,29	60,08	58,91	61,38	63,49	68,21	65,47	73,66	63,45	60,2	62,73	62,35	67,90	70,21	57,90	60,02
CaO total	0,18	0,62	0,26	0,26	0,18	0,28	0,18	0,25	0,26	1,64	0,26	0,23	0,20	0,27	0,29	2,73	2,14
stable	0,06	0,14	Trace	0,07	0,03	0,07	Trace	0,12	0,17	0,80	0,06			Trace		0,20	0,08
soluble[c]	0,12	0,48	0,26	0,19	0,15	0,21	0,18	0,13	0,19	0,84	0,20	0,23	0,20	0,27	0,29	2,53	2,06
exchangeable	0,12	0,10	0,07	0,10	0,10	0,12	0,12	0,10	0,19	Not det'd.	0,20	0,07	0,10	Not det'd.	0,12	0,3	0,27
MgO total	0,08	0,27	0,09	0,12	0,13	0,07	0,06	0,11	0,14	1,83	0,02	0,04	0,06	0,11	0,17	1,11	0,95
stable	Trace	0,03	Trace	0,04	Trace	0,03	Trace	0,07	0,08	0,54	Trace	Trace	0,06	Trace	0,06	0,10	0,03
soluble[c]	0,08	0,24	0,09	0,08	0,13	0,04	0,06	0,04	0,06	1,29	0,02	0,04	Trace	0,11	0,11	1,01	0,92
exchangeable	0,02	0,04	0,02	0,02	0,02	0,02	0,02	0,02	0,02	Not det'd.	0,02	0,04	"	Not det'd.	0,04	0,33	0,23
MnO total	0,19	0,19	0,19	0,17	0,21	0,31	0,33	0,22	0,21	0,21	0,69	0,53	0,52	0,72	0,32	0,72	0,27
K_2O total	0,15	0,12	0,08	0,12	0,15	0,14	0,16	0,11	0,10	0,24	0,15	0,15	0,07	0,07	0,12	0,20	0.15
stable	0,05	0,05	0,02	Trace	0,08	0,03	0,02	Trace	0,00	0,14	0,02	Trace	0,05	0,03	0,10	0,10	0,08
soluble[c]	0,10	0,07	0,06	0,12	0,07	0,11	0,14	0,11	0,04	0,10	0,13	0,15	0,02	Not det'd.	0,02	0,10	0,07
exchangeable				Trace	Trace				Not det'd.	Not det'd.	Trace	Trace	0,01	"	0,02	0,02	0,02
Na_2O total	0,09	0,06	0,09	0,06	0,09	0,11	0,10	0,10	0,32	0,35	0,09	0,10	0,09	0,16	0,17	0,43	0,38
stable	0,02	Trace	0,02	Trace	0,02	0,04	0,03	Trace	0,25	0,14	0,01	0,02	Trace	0,06	0,10	0,17	0,08

Table 6 continued

Determination	Profile number and depth, cm																
	442										17					74	
	0–10	10–20	30–40	70–80	170–180	350–36	570–580	810–820	1190–1200	Rock	0–10	40–50	100–120	300–320	400–420	0–10	25–35
Na_2O soluble[c]	0,07	0,06	0,07	0,06	0,07	0,07	0,07	0,10	0,07	0,21	0,08	0,08	0,09	0,10	0,07	0,26	0,30
exchangeable																0,02	0,02
TiO_2 total	5,00	4,21	5,62	4,64	5,03	3,45	3,93	4,72	5,11	4,42	6,64	5,99	4,98	4,72	4,29	1,74	1,68
Total content	100,74	100,25	100,51	100,56	100,69	100,74	100,54	101,16	100,67	100,11	100,11	100,02	100,27	100,67	100,47	100,18	100,79
$\frac{SiO_2}{Al_2O_3}$ of total quantity	2,47	2,50	2,38	2,57	2,19	1,87	1,57	1,89	1,26	1,90	2,09	1,87	1,85	1,44	1,57	2,02	1,85
of soluble part	1,69	1,66	1,64	1,85	1,60	1,36	1,13	1,53	1,05	1,72	1,84	1,69	1,70	1,36	1,45	1,56	1,75
$\frac{SiO_2}{Fe_2O_3}$ of total quantity	3,99	3,83	3,88	3,88	3,67	3,43	2,66	3,03	1,94	2,82	4,81	4,29	4,35	2,07	2,31	4,04	4,11
of soluble part	2,66	2,48	2,62	2,80	2,64	2,57	1,86	2,47	1,64	2,58	4,25	3,88	3,99	2,00	2,14	3,30	2,83
$\frac{CaO}{MgO}$ of total quantity	1,40	1,40	1,76	1,34	0,85	2,44	1,83	1,83	1,10	0,55	—	—	—	1,46	1,04	1,49	1,37
of soluble part	0,92	1,22	1,77	1,46	0,73	3,17	1,83	1,95	1,89	0,43	—	—	—	1,52	1,60	1,52	1,34

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[a] Stable in relation to the mixture of HCl, H_2SO_4 and HNO_3.

[b] Soluble in the mixture of these three acids.

[c] Including exchangeable.

Note: Comma represents decimal point.

basically the same as that for the total content of these acids. In samples in which fulvic acids predominate the value for mobile humic acids was even higher than their total, the value for mobile humic acids was even higher than their total, probably as a result of the high mobility of humic acids partly extracted from the soil on decalcification.

This high mobility of humic acids is due to their high content of peripheral hydrophilic groups and the weak revelation of the aromatic nucleus responsible for their hydrophobic properties. Thus, the mobility of the humic acids is very high in these soils and probably greater than that of the humic acids in soils of the temperate and subtropical belts that have already been studied (16, 25). Zonn and Li-Chen-kvey (27) have already noted the predominance of fulvic acids and mobile forms of humic acids in the humid tropic soils of Southern China. The procedure for studying the composition of organic matter should therefore be amended to include determination of forms that are more mobile than substances in the first group.

In addition to these extremely active organic components, there is, as previously observed in tropical soils (21), a large amount of slightly mobile forms that are not extracted from the soil, but form a residue firmly combined with the mineral part of the soil.

The chemical analyses are well confirmed by measurements of the optical density of humic acids (Fig. 1). The humic acids were optically more dense in soils the organic matter of which contained a great deal of humic acids. It can therefore be assumed that conditions that are favorable to the accumulation of humic acids also facilitate their high condensation.

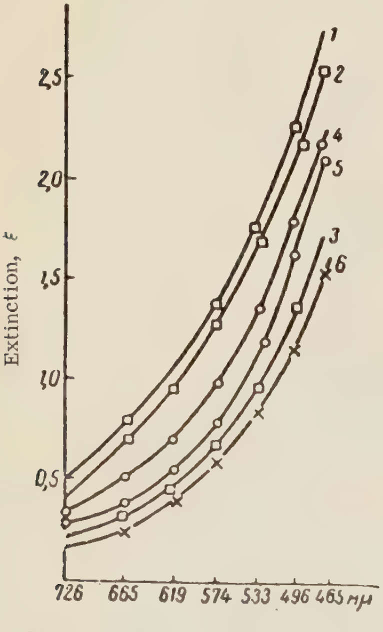

Fig. 1. - Optical density of soil organic matter from the hilly territory of Northern Viet-Nam.

Table 6 gives total chemical analysis for the soils under consideration and the results of determining their content of soluble and insoluble substances in a mixture of sulfuric, hydrochloric, and nitric acid by the method described by Rode (22). Data for exchangeable forms are also given for calcium, magnesium, potassium, and sodium (recalculated from Table 4).

In all three profiles the pronounced hydration of the mineral part of the soil is shown by the fact that ignition losses are very great in the lower as well as the upper horizons. Thermal analysis data (Fig. 2) confirm this hypothesis (the endothermic peaks at 100° C-125° C are very great).

The total content of silica is approximately the same in all three profiles, but there is considerably more stable silica (almost entirely quartz) in profile 442 than in profiles 17 and 74, because of the nature of the soil-forming parent materials: the shales on which profile 442 were formed contain quartz while the andesite-basalts and tuffs on which profiles 17 and 74 were formed contain little or no quartz.

The great increase in sulfur content in profile 74 is also due to the nature of the soil-forming parent material; volcanic tuffs normally have a very high sulfur content.

All the samples had a high phosphorus content, but this was to be expected from references in the literature (14, 19); its content is especially high in soils formed on basic rocks.

There were significant amounts of aluminum in all the samples analyzed, but extremely little stable aluminum; it can therefore be assumed that the stable silica is mainly quartz and that the amount of stable aluminosilicates is very slight. When the chemical analysis data are compared with thermograms (Fig. 2) it becomes apparent that the aluminum is mainly incorporated in kaolinite and halloysite but that considerable quantities are also present as free hydroxides, (hydrargillite, etc.).

The thermograms do not explain the enhanced exchange capacity of profile 74, which has already been mentioned. Since kaolinite and halloysite have the same total chemical composition and the same thermographic curve, additional X-ray studies were made at the laboratory of the Institute of Geology, Petrography, Mineralogy, and Geochemistry of the USSR Academy of Sciences. These studies revealed that metahalloysite (7.30 Å and 1.48 Å lines) predominates in the composition of the clay fraction of profile 74. This fully explains the high exchange capacity and some of the other properties of this soil.

The amount of iron in all three soils is also very high, but there is even less stable iron than stable aluminum; the higher content of stable iron and stable aluminum in the samples taken from the lower parts of profile 442 is due to the less extensive weathering of these deep horizons.

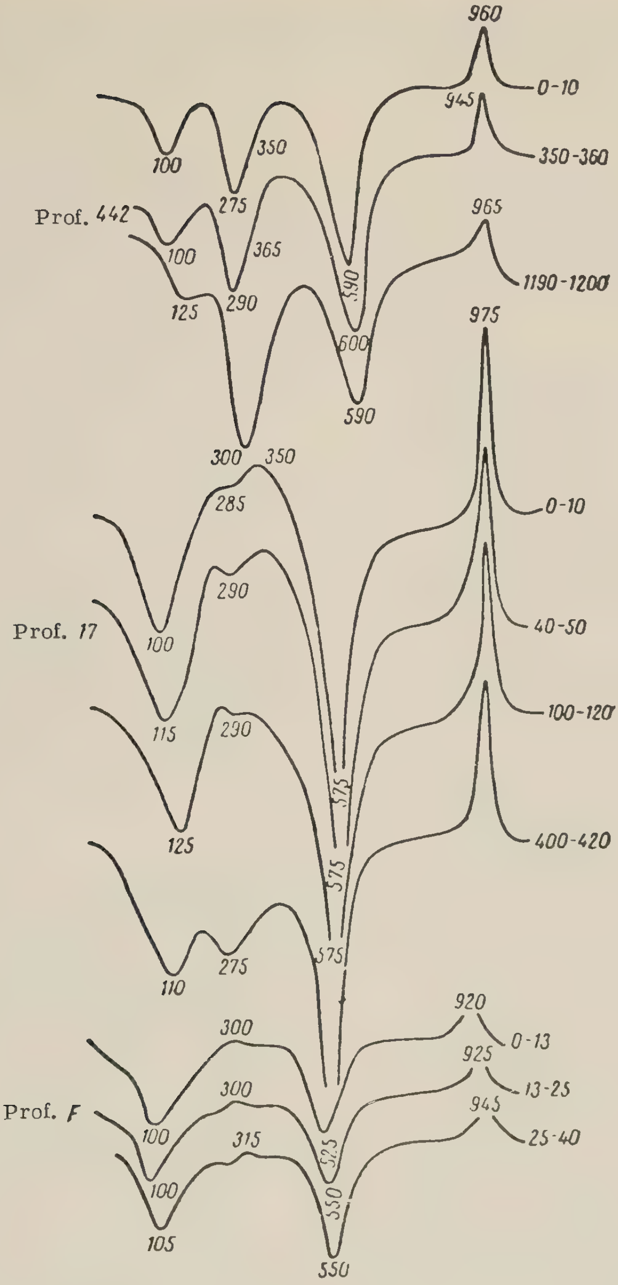

Fig. 2. - Thermograms of soil samples from the hilly territory of Northern Viet-Nam. (The values to the right of the curve show the depth in centimeters).

The content of calcium and magnesium, which is very low in profiles 442 and 17, is approximately ten times as great in profile 74. This difference in the total content of the alkali earths is responsible, as already indicated, for the differences in the composition of available cations and humus. The enhanced calcium and magnesium in the soil-forming parent material of profile 442 is due to its shallow weathering. The content of more available potassium and sodium is little different between profiles 442 and 17 on the one hand and profile 74 on the other; insignificant amounts were present in all samples.

There is a distinct variation in titanium content between the soils — 4%-6% in profiles 442 and 17, this is similar to the values given for some of the soils of Southern China in (18). The titanium content of profile 74 is noticeably lower due to its greatly reduced content of volcanic tuffs.

Manganese content is quite considerable in all the profiles, especially in the soils developed on basalts and volcanic tuffs.

Let us examine the alteration in the total chemical composition of the soils through the profile.

There are two distinct levels in profile 442 — a lower level below 570 cm and an upper level above 570 cm. In the lower part of the profile, in which the reaction is near neutral, SiO_2 content is typically lower and R_2O_3 content higher; it is evident that active weathering processes are under way in this part of the profile and that there is removal of silica and accumulation of sesquioxides. In the upper part of the profile there is distinct reduction in sesquioxide content and a corresponding increase in silica content, especially stable forms of silica. It therefore follows that sesquioxides are being removed from this part of the profile. The texture of the soil confirms these conclusions: it is finest in the central part of the soil profile and becomes coarser below, because of the reduced extent of weathering and above, because of intensified removal of fine particles.

The distribution of alkali earths and alkali shows that their active removal begins in the initial stages of weathering and that their content subsequently becomes stable in all the horizons of the weathering crust and the soil, as shown by their approximately equal content throughout the profile.

The differences in total chemical composition with depth in profile 17 are due to the presence of small iron concretions at a depth of more than 3 m. This also explains the increased iron and the reduced content of silica and, in part, aluminum in the lower horizons. The increased content of silica, especially stable silica, in the upper horizons and the simultaneous reduction in the content of aluminum and iron is in full agreement with the slight coarseness in the texture of these horizons.

There is insufficient information for profile 74 to assess alterations in the total chemical composition with depth.

We shall attempt to reveal the specific features of each of the three groups of soil-forming parent materials that account for the distinctive features of the three profiles described.

The first group of rocks (soils represented by profile 442) comprise shales, gneisses, granites, rhyolites, and other acid rocks containing a considerable amount of quartz and certain other minerals that are quite resistant to weathering. Intensive leaching and the slow liberation of bases account for the development of weathering under conditions of base deficiency (acid medium, dilute solutions). These rocks are relatively poor in iron and the amount liberated on decomposition of the minerals is insufficient to give the weathering products a stable structure.

The rocks of the second group are richer in bases and, which is especially important, in iron. The weathering of these rocks, as in the preceding group, follows the same pattern but loss of bases, is greater than their liberation on weathering; there is therefore insufficient bases in the formation of the weathering crust and soils. On the other hand, a considerable amount of the iron liberated on weathering is a cement that creates a stable structure for the weathering products and this ensures good aëration of the soils formed on them and prevents the development of gleying processes.

The considerable amount of bases liberated on weathering is a feature of the third group of rocks. The third group of rocks has a considerable amount of bases liberated during weathering. Volcanic tuffs, marls, and poorly crystalline limestone containing a large quantity of admixtures readily give up bases. The weathering crust and soils formed on them are considerably richer in bases; the input of bases on weathering exceeds loss. There is very little iron in these rocks. Those that are richer in iron give rise to better structured weathering crusts and soils, but this is only an additional feature — the main feature of the group is the high base content.

Let us consider the classification of the soils studied.

The first two profiles (profiles 442 and 17) belong to the extensive group of tropical soils known as lateritic soils (4, 24), latosols (15), ferrallitic soils (1), typical laterities — mixed allitoferrites and ferroallites (13). Kellog (15) who first gave a full description of the characteristics of this group formulated the following nine features of latosols (these features were repeated in general outline by Aubert [1]; most of them are also to be found in Gerasimov's definition [13]).

1. A low $SiO_2:R_2O_5$ ratio in the clay fraction (Aubert added, the quartz-free part of the soil) taking his limit the previously established value of the $SiO_2:Al_2O_3$ ratio of two or below.

2. Low exchange capacity of the clay mineral;

3. Low content of primary minerals, except for low stable minerals;

4. Low content of soluble matter;

5. Relatively high aggregate stability;

6. Red color or reddish tinge to other colors;

7. Absence of illuvial-accumulative horizons in most cases (they may exist in some soils of the group);

8. Thin organic horizons (forest litter) above horizon A_1; and

9. Relatively low silt content by comparison with other soils.

In the light of what has been said previously, the soils here considered have these attributes; the data at our disposal does not show structural stability but field observations confirm its stability. One attribute (low silt content) is not typical of the soil of profile 442. It emerges from an examination of extensive material that a low silt fraction is general but not invariable.

An additional attribute can be deduced from the information given previously and from the unpublished data and materials of other authors (21); fulvic acids are greatly predominant over humic acids and are highly available forms.

The term "ferralitic soils" suggested by Aubert seems the most suitable. It is similar to the terms "allitoferrites" and "ferroallites" advanced by Gerasimov as descriptive of the further subdivision of this soil group. In our opinion, soil profiles 442 and 17, which are ferrallitic soils, are of different genetic types. Their differences are primarily in physical properties — structuring and porosity — and these properties characterize the water and air regimes. As a result of this, gleying processes occur in the rainy seasons in soils developed on shales, granites, and other non-basic rocks; these processes are associated with slight water-permeability, which a number of authors (26, 23) see as a typical feature of humid tropical soils. The processes of differentiation of the profile often observed in them are described as podzolization by some soil scientists.

Soil developed on basic (and medium quartz-free) rocks (profile 17) are highly structured, extremely porous, well aerated and permeable, and show no signs of gleying and very slight differentiation of the profile. Naturally enough the methods for agricultural use of these soils are also different. On soils of the first group, for example, plantations of perennial crops must be cultivated fairly frequently to improve the water and air regime and to activate biological processes, whereas soils of the second group do not need cultivation. In the explanatory text to the soil map of Northern Viet-Nam (12) I have classified these soils as belonging to the red and yellow lateritic soil groups (profile 442) and to the red strongly lateritic groups (profile 17).

Although Kellog (15) distinguishes a number of types he does not give a clear description. It would appear from indirect indications in the article that our soils can be compared with his "reddish-yellow latosols" (profile 442) and red earth latosols" (profile 17). My suggested terms (7) of "red-yellow lateritic soils of the humid tropical forest" and "red lateritic soils of the permanently humid tropical forest" emphasize the conditions under which these soils were formed. This clarification is essential since soils that are similar both morphologically and in a number of properties (especially total chemical and mineralogical composition) have often been described by soil scientists under different bioclimatic conditions where they are relictual formations with quite distinctive regime and more dynamic properties (reaction, composition of exchangeable cations, etc.).

On the soil map of Africa, south of the Sahara, (3) these soils are respectively called beige-yellow ferrallitic and red ferralitic.

On the basis of what has been said, it appears preferable that the soils described by profiles 442 and 17 should be called, respectively, "red-yellow ferrallitic soils of permanently humid tropical forests" and "dark red ferrallitic soils of permanently humid tropical forests".

The soil of profile 74 belongs to the extensive group of black tropical soils that have been distinguished by a number of authors. The soil in the group that most nearly corresponds to profile 74 is margalitic soil (19, 2) that is black, neutral in reaction, has a high exchange capacity, and an almost completely base saturated adsorption complex. The typical nature of these features for the black soils of Northern Viet-Nam and their connection with volcanic tuffs, carbonate sandstones, and marls, on which margalitic soils normally develop, prompt this conclusion (12).

However, subsequent research has revealed that clay minerals of the halloysite group predominate in these soils, whereas the montmorillonite group is typical of margalitic soils. The contradictory nature of the composition of the organic matter, in which highly available humic acids predominate has also become apparent. These facts indicate that in addition to those of its properties that are typical of margalitic soils, this soil also has important properties that are typical of ferrallitic soils. On this basis, soils similar to profile 74 are classified as a special transitional group of ferrallitic-margalitic soils. Subsequent research should reveal how widely distributed are such soils and how stable are their properties.

All the three soils considered here are found under the same bioclimatic zone; therefore has to be decided which type is the zonal group. This problem is of great difficulty in the humid tropics where the soil-forming parent materials are extremely diverse and have a fundamental effect on the nature of the soils and where alterations in the mineral part of the soil during weathering and soil formation are profound and irreversible. The difficulties are considerably enhanced by the fact that the differences between the base rocks and their weathering products are considerably greater in the humid tropics than under different bioclimatic conditions.

Therefore, when solving the problem of the zonal group we had recourse to two criteria. The first criterion was that the properties of the zonal group should correspond to the biogeochemical conditions of the zone. Ferrallitic-margalitic soils do not fully satisfy this criterion (neutral reaction, high base saturation, and humus composition of the organic matter are not typical for the conditions of leaching and forest vegetation). The two other soils satisfy the biogeochemical conditions of the zone. The second criterion is that the zonal group should be the group that, within the bioclimatic zone, is associated with the greatest diversity of soil-forming parent materials and with the widest range of their properties. The dark-red ferrallitic soils of permanently humid tropical forests are only associated with two definite groups of soil-forming parent material — basic igneous and intermediate rocks and marmorized pure limestones. The red-yellow ferrallitic soils of permanently humid tropical forests are connected with a far wider variety of soil-forming parent materials: various sedimentary and metamorphic acid igneous and acid effusive rocks. The red-yellow ferrallitic soils can therefore be taken as the zonal group for the permanently humid tropical forest zone.

Each of the three profiles described shows the most typical features of the groups to which it belongs. On the other hand these groups embrace widely differing soils that are clearly grouped into subgroup, genera, species, types, and variants. It is not, however, possible in a journal article to include the vast amount of material needed to examine this question. I would merely note that the transitions between the groups, the differences of which are due to the nature of the soil-forming parent materials, take place as transitional genera and not transitional subgroups.

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SOILS OF THE HUMID MONSOON TROPICAL ZONE OF BURMA[1]

V. G. ROZANOV and I. M. ROZANOVA, Moscow State University

The humid monsoon zone is the most typical region of tropical Burma. It includes the coastline, the Tenasserim and Arakan low mountain chains, and the north and south of the central belt. Annual precipitation, which is highly seasonal, varies between 2,000 mm and 5,000 mm and the temperature is consistently high (25°C-27°C).

The tropical evergreen and semi-evergreen forests of the coastal and low hill districts give way in the central belt to monsson mixed forests that shed their leaves in the dry season.

The commonest soils of this zone in Burma are red-brown tropical evergreen forest soils, which may also be called red loams (Chhibber [2] took the term from Fageler to distinguish these soils from red earths). They occur mainly on slopes up to 1,000 m above sea level in the Arakan and Tenasserim mountains and in the low mountain district in the north of the central belt.

These soils form beneath a tropical forest canopy of exceptional luxuriance. The biological cycle is very extensive under these conditions and the humid monsoon tropical climate also promotes the development of a major geological cycle, thus leading to intensive processes of weathering and soil formation. Despite this the soil does not give the expected impression of an old and thick formation, apparently because of the general geological youth of tropical Burma and the intensive denudation and continual rejuvenation of the soil on mountain slopes.

It has been suggested (formerly by Fageler [4] and for Burma by Chhibber [2]) that red-brown tropical soils are the first stage in the development of red earths. Although the view of the evolution of these soils is clearly applicable in certain cases it does not negate the fact that they can be formed and are at present being formed in a way that bypasses the developmental stage. At all events the two genetic groups have a separate existence in Burma in different landscapes and are quite clearly distinguishable from each other by morphological, chemical, and physical indixes, and by contemporary soil loaming factors.

The profile of Burmese red-brown forest soils is usually quite thin (not usually more than 1 m), but may reach 1.5 m-2 m on smooth levelled slopes. Nevertheless the profile and the genetic horizons are quite distinct. The surface humus-accumulative (A) horizon is followed by a B horizon of clay accumulation beneath which there is a transitional B/C horizon in direct contact with the unweathered parent material. The parent material varies; it is mainly clay shales with a few areas of ultrabasic and basic crystalline rocks in Arakan and N. Burma, while in Tenasserim it is phyllites, quartzites, granites, and gneissose granites. Clay shales and phyllites are the usual parent materials.

The soil is red-brown in color, varying from dark gray-brown or reddish-brown in the surface horizon to light red or even rose (on granites and quartzites) in the lower part of the profile. Color transition down the profile is as extremely gradual as the general transitions between the profiles. The upper soil horizon is quite friable, since it is greatly penetrated by roots, and its structure is stable and blocky. Lower down the structure gradually becomes coarser and the B horizon is somewhat compacted. Even lower down the structure once again becomes friable due to the presence of considerable quantities of rock fragments.

The commonest variant of these soils is a thin red-brown forest mountain soil with considerable stoniness in the profile. This soil covers most of the steep mountain slopes in the districts mentioned previously. The B horizon differs greatly from the A horizon. Total chemical analysis (Table 1) clearly reveals the relative accumulation of silicic acid in the upper horizon which is relatively deficient in sesquioxides. The sesquioxide content of B horizon is noticeably greater than that of the A horizon. Since there are less sesquioxides and clay particles in the upper horizon by comparison with the lower horizon in almost all of the Burmese soil groups, this is definitely not a specific feature of the red-brown forest soils. We are inclined not to see the whole explanation in leaching or in some sort of "tropical podzol formation." Although there is certainly leaching and transportation of substances down the profile from the upper horizon, that is not the only process involved in the formation of this soil profile. A considerable part is also played by the processes of superficial removal of particles and metamorphic gleying in situ in the central and lower parts of the profile. Particle-size analysis of these soils reveals that the upper horizon contains considerably less of the clay fraction and that there is a corresponding relative increase in the sand fraction. The content of clay fraction is highest in the B horizon, where its content may be twice that in the upper horizon. It is most probable that this is associated with removal of clay particles in surface runoff during torrential rain and with the simultaneous intensive formation of clay in the soil layer.

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[1] This communication arises from studies carried out by the Burmese Land Utilization Office and directed by Soviet specialists. The production of a 1:253,000 soil map of the country, which was the main object of the work, has now been completed for approximately two-thirds of the territory. The soviet specialists B.G. Rozanov and M.S. Simakov worked in 1957 and B.G. Rozanov, I.M. Rozanova and I.I. Karmanov in 1958 and 1959. The authors would like to thank U On Pe, the Director of the Burmese Land Utilization Office, and his deputies, U Pe Sain and U Tin Maung Chi, for their great assistance in organizing work and in supplying the best possible conditions for the normal work of the Soviet specialists. They are also grateful to Professor S.V. Zonn for critical remarks on the text.

It is interesting to note that although soil texture invariably becomes gradually finer with depth (in particular the content of the clay fraction increases) adsorption capacity does not follow the same pattern. The adsorption of these soils is generally low (10 meq-25 meq per 100 g of soil in the upper horizon) and remains invariable or even declines slightly with depth and is lowest on transition to the parent material. The exchange capacity of the soil is probably mainly associated with the clay and organic complex and not with the clay minerals, as has been confirmed for other soils. The soil is slightly acid but quite considerably unsaturated (Table 2).

Red-brown forest soils are relatively rich in humus (3%-4% in the upper horizon), but there are quite considerable variations in humus content between soils. Thus, humus content is 5%-6% in the subgroup of dark red-brown forest soils and may even reach 10% on occasions. Humus content decreases gradually with depth. The C:N ratio in the humus varies between 10 and 13 in Tenasserim and between 12 and 17 in North Burma. The considerable narrowing of this ratio down the profile is a general feature of Burmese soils.

Provincial features in Tenasserim on the one hand and in Arakan and North Burma on the other are mainly associated with the petrography of these districts. Although the soils of Tenasserim contain more humus they are more acid, less saturated with bases, poorer in available compounds of phosphorus and potassium, and slightly richer in nitrogen.

Little use is made of red-brown forest soils for field crops although a primitive form of clearance agriculture has been practiced on them in the mountain district. The peoples of

Table 1

Partial total chemical analysis of red-brown forest soils, % of sample dried at 105°C[a]

Profile No.	District	Depth, cm	Ignition loss	SiO_2	Al_2O_3	Fe_2O.	CaO	MgO	MnO	P_2O	SO_3	Total
62-P	Katha, North Burma	0—12	12,74	54,45	17,09	9,88	0,79	0,97	0,24	0,04	0,48	98,68
		45--57	12,10	44,71	26,72	12,81	0,88	1.15	0.24	0,01	0,38	99,00
		100—110	11,22	45,47	25,85	12,85	0,99	1,25	0,21	0,02	0,52	98,38
		140--150	11,43	46,98	23,77	11,59	2,10	1,48	0,30	0,02	0,57	98.12
5-A	Mergui, Tenasserim	0—12	6,98	74,47	15,27	2,76	0,11	0,04	0,07	0,07	Not det'd.	99,77
		12—25	8,09	69,42	18,11	3,37	0,21	0,04	0,09	0,07	"	99,40
		30—42	8,20	66,85	18,74	4,32	0,18	0,06	0,07	0,06	"	98,48
		100—110	9,28	58,01	25,49	4,86	0,21	0,13	0,07	0,05	"	98,00
4-B	Chin Hills, Arakan	0—12	12,50	60,10	13,94	7,44	0,43	0,37	0,05	0,26	Not det'd.	95,09
		25—30	12,20	59,05	18,30	8,34	0,48	0.57	0,11	0.18	"	98.22
		62—70	13,50	52,05	21.81	9,93	0,46	0,57	0,18	0.14	"	97,64
		140—150	11,20	53,10	19,12	9,95	0,11	0,21	0.18	0,17	"	94,05

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[a] All the analyses in this work were directed by I. M. Rozanova.

Note: Comma represents decimal point.

Table 2

Analytical data for red-brown forest soils

Profile No.	District	Depth, cm	pH	Humus, %	C:N	Exchangeable bases, meq/100 g			Hydrolytic acidity, meq/100 g	Base saturation, %	Content of particle diameters <0.002 mm %
						Ca	Mg	Total			
62-P	Katha, North Burma	0—12	6,8	4,31	13,5	6,3	1,6	7,9	2,65	74,5	38,00
		45—57	6,5	1,26	9,9	5,2	1,4	6,6	4,34	60,6	47,81
		100—110	6,3	0,90	—	5,1	0,9	6,0	3,64	62,5	39,72
		140—150	6,1	—	—	4,3	0,9	5,2	2.77	65,0	29,64
125-K	Katha, North Burma	0—10	6,5	1,36	10,1	4,2	3,2	7,4	2,18	77,1	12,44
		35—45	6,5	0,67	9,3	1,8	0,9	2,7	1,67	62,8	22,88
		73—83	6,3	0,41	5,5	1,0	1,9	2,9	2,65	51,8	31,24
		145—155	6,0	—	—	1,3	1,2	2,5	2,31	52,1	32,64
5-A	Mergui, Tenasserim	0—12	5,9	1,48	16,0	3,3	2,9	6,2	2,77	69,0	16,25
		12—25	5,6	0,88	10,1	2,4	2,4	4,8	2,63	64,8	16,80
		30—42	5,2	0,74	—	2,1	2,3	4,4	2,68	62,0	39,00
		100—110	5,2	—	—	2,2	2,3	4,5	2,17	69,8	42,80
63-A	Mergui, Tenasserim	0—12	5,6	2,32	11,3	4,1	1,2	5,3	5,70	48,2	16,69
		20—30	5,0	2,20	16,0	2,5	0,8	3,3	4,00	45,2	34,08
		50—60	5,3	1,31	—	2,5	0,8	3,3	1,85	63,4	34,72
		80—90	5,7	—	—	2,3	1,0	3,3	2,22	60,0	16,24
4-B	Chin Hills, Arakan	0—12	5,8	3,70	13,6	9,2	2,7	11,9	0,72	94,4	22,41
		25—30	5,5	0,88	10,2	7,8	4,3	12,1	6,00	66,9	46,02
		62—70	5,6	0,41	—	7,0	6,2	13,2	5,78	69,8	49,25

Note: Comma represents decimal point.

the foothills use them readily for fruit crops. The areas of tropical fruit and rubber plantations in Tenasserim are confined to these soils.

These soils are normally replaced by tropical monsoon forest soils on the lower parts of slopes in the foothills and the sides of low hills. Such soils are most abundant in the Pegu Yoma hill country and in the low mountain of North Burma at altitudes of up to 500 m-600 m, usually either on the sides of low hills or on the lower parts of mountain slopes.

Chhibber (2) and later investigators, including Stamp (6) and Coggin Brown (3), included these soils with red loams and failed, in our opinion incorrectly, to distinguish them as an independent group. These soils are an independent genetic group with specific features and their separate recognition should not be refused because there are countless transitional forms between them and the red-brown forest soils.

The profile of these soils is yellow-brown or brown in color, darker in the upper horizon and lightening gradually downwards. The genetic horizons are clearly distinguishable although the transitions between them are gradual. The thickness of the profile down to the parent material is normally 1. 5 m-2 m, although it may be greater on levelled relief or on deluvium. Shallow soils may be found on the steeper slopes. Carbonates are normally absent from the profile of these soils, except that carbonate varieties of yellow-brown forest soils are formed where there are outcrops of limestones in the clay shale beds; carbonate content increases gradually with depth and is greatest in the parent material. Yellow-brown forest soils are formed on clay shales and sandstones and in places (in Tenasserim for example) on acid crystalline rocks.

Yellow-brown forest soils have a blocky structure and useful physical properties. As in the previous group the central part of the profile is typically somewhat compacted, although to a lesser degree.

These soils also have apparent provincial features. In Tenasserim they are more acid and less base saturated and have a high humus content.

Of the several subgroups of yellow-brown forest soils that differ perceptibly in agricultural and other indixes, particular mention should be made of dark, light, and meadow types. As with red-brown forest soils the surface horizon is clearly relatively impoverished

Table 3

Partial total chemical analysis of yellow-brown forest soils, % of sample dried at 105°C

Profile No.	District	Depth, cm	Ignition losses	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	MnO	P_2O_5	SO_3	Total
517-W	Taunggyi, Pegu Yoma	5—15	10,72	72,35	10,35	4,96	0,28	Not det'd.	0,24	Not det'd.	Not det'd.	98,59
		25—35	9,71	63,15	19,61	8,25	0,18	"	0,09	"	"	100,99
		67—75	9,54	61,69	20,52	9,05	0,46	"	0,14	"	"	101,47
		105—115	9.87	62.38	15,75	8.80	0.53	"	0.11	"	"	97,44
7-B	Chin Hills, Arakan	0—8	15,70	64,76	13,37	3,98	0,15	0,29	0,13	0,20	"	98,60
		30—35	8,13	67,85	21,36	3,28	0,25	0,63	0,13	0,12	"	101,77
		60—65	6,80	68,34	16,71	4,67	0,11	1,18	0,13	0,11	"	98,05
1-A	Mergui, Tenasserim	0—10	7,81	79,56	9,39	2,02	0,16	0,09	0,02	0,06	"	99,11
		27—37	8,69	68,37	17,22	3,29	0,14	0,33	0,05	0,09	"	98,18
		68—80	7,95	62,48	23,03	4,04	0,16	0,15	0,05	0,09	"	97,95
		110—115	8,75	59.36	23.90	5.80	0.18	0.04	0.21	0.07	"	98.31
35-P	Shwebo, North Burma	0—12	7,52	73,69	11,98	4,79	0,15	0,93	0,05	0,01	0,28	99,40
		54—66	7,16	74,15	12,19	4,79	0,13	0,64	0,07	0,01	0,35	99,48
		90—102	7,00	74,63	12,08	4,33	0,10	0,57	0,06	0,03	0,35	99,21
		150—155	6,94	74,95	11,92	4,69	0,07	0,44	0,15	0,03	0,24	99,44

Note: Comma represents decimal point.

Table 4

Analytical data for yellow-brown forest soils

Profile No.	District	Depth, cm	pH	Humus, %	C:N	Exchangeable cations, meq/100 g			Hydrolytic acidity, meq/100 g	Base saturation, %	Content of particle diameters <0. 002 mm,%
						Ca	Mg	Total			
517-W	Taunggyi, Pegu Yoma	5—15	5,6	4,18	12,7	4,2	6,7	10,9	6,84	61,6	23,00
		25—35	5,7	1,20	10,5	2,7	6,5	9,2	5,86	60,8	33,15
		67—75	5,7	0,62	8,9	2,1	4,4	6,5	5,36	54,9	31,95
		105—115	5,7	—	—	2,6	4.5	7,1	5,30	57,2	26,75
7-B	Chin Hills, Arakan	0—8	6,1	5,94	12,6	1,1	6,8	7,9	5,69	57,9	33,92
		30—35	6,0	0,81	9,8	2,1	4,2	6,3	3,79	63,0	36,17
		60—65	6,0	0,20	7,3	1,7	2,5	4,2	3,01	58,3	25,10
1-A	Mergui, Tenasserim	0—10	5,4	1,41	11,3	2,6	1,6	4,2	3,49	54,5	13,68
		27—37	5,1	1,32	10,8	2,6	1,8	4,4	1,42	76,0	36,64
		68—80	5,0	0,64	6,5	1,2	1,2	2,4	2,07	53,3	45,76
		110—115	5,0	—	—	0,8	1,2	2,0	1,91	51,3	39.40
35-P	Shwebo, North Burma	0—12	5,8	0,61	11,0	4,7	1,8	6,5	4,18	60,7	37,30
		54—66	5,8	0,24	6,5	3,9	1,9	5,8	3,04	66,0	39,14
		90—102	5,6	0,20	—	4,1	2,0	6,0	2,81	68,5	35,82
		150—155	5,6	0.10	—	4,0	1,7	5,7	2,07	73.1	31.02
209-K	Myitkyina, North Burma	0—10	6,7	1,06	8,0	7,2	8,8	16,0	5,65	73,7	9,40
		20—30	6,7	1,07	7,2	9,1	3,5	12,6	6.51	66,0	21,90
		55—65	6;2	0,72	5,5	5,3	4,9	10,2	4.87	67,5	16,32
		100—110	6,4	0,50	—	4,4	4,1	8,5	4,01	68,0	22,48

Note: Comma represents decimal point.

of sesquioxides (Table 3) and clay particles, which are most plentiful in the center of the profile. It should, however, be noted that the redistribution of the elements within the soil layer is less pronounced than in the red-brown forest soils; the soil profile is more uniform below the A horizon. Allitization is also slightly less pronounced in yellow-brown forest soils (Table 4).

The soils have a slightly to strongly acid reaction with a distinctive geographical distribution of acidity. The pH of the upper horizon is between 6 and 6. 5 in the soils of North Burma (average 6. 3 for 20 profiles) decreasing to 5-6. 5 (average 5. 6 for 26 profiles) further to the south in Pegu Yoma and reaching its lowest values of between 4. 5 and 5 (average 4. 9 for 9 profiles) in Tenasserim. Adsorption capacity of yellow-brown forest soils is not high and the level of base saturation, which varies between 30% and 80%, reveals the same geographic distribution as soil acidity.

Since these soils are most favorably situated it is natural that they should be widely used for fruit and rubber plantations in the south.

The lateritic soils found in places in south Burma are very similar in appearance to yellow-brown forest soils. The total area of lateritic soils and laterites in Burma is slight and they are confined to the southern tip of Arakan, the southern end of Pegu Yoma and the Tenasserim seaboard, especially in the Moulmein district.

We distinguish laterites and lateritic soils, the first being variously allitized weathering crust similar in external features to the definition given many years ago by Buchanan (1). In this "classical" definition laterite is a fairly dense but comparatively easily worked variegated soil of cellular structure, rich in the hydroxides of iron and aluminum that hardens fairly rapidly on exposure to the atmosphere to form a quite durable building material.

Laterites of this type have been described in South Burma, where before the war thousands of tons were produced annually by opencast working, mainly for the construction of roads and secondary buildings. When laterite has an earthy appearance it has always been formed at depth and emerges at the surface when the surface layer of soil has been entirely removed by erosion after the felling of a forest. This is clearly apparent in the vicinity of Rangoon. In such cases a ferruginous layer of laterite that has been exposed to the atmosphere and is already quite hard is exposed at the surface. As laterite hardens or "ages" at the surface its relative enrichment with sesquioxides is further increased since the softer accumulations of kaolinite are mechanically washed out to leave only the iron-aluminum matrix.

The two species of laterite that are distinguished are pisolitic and vermicular (cellular). In Burma a lateritic crust always consists of pisolitic laterite underlain by vermicular laterite. The former, which usually contains more iron and aluminum, is usually shallow (not exceeding 1 m) whereas the latter may be many meters thick.

It is thought that laterite is always very rich in sesquioxides and almost devoid of silicic acid. This is not true for conditions of Burma. The considerable range of sesquioxide content in Burmese laterites is related to the extent of lateritization and also, probably, to the composition of the initial parent material. Table 5 shows analytical data for a typical Burmese laterite from laterite open-pits 50 km to the north of Rangoon. Laterite is here produced for road building. The R_2O_3 content reaches 30% and the piezolitic laterite (90 cm-100 cm) is richer in sesquioxides than the lower lying vermicular layer. In other cases R_2O_3 content may not exceed 20%. It is only in laterites that have already been "aged" to a certain extent that R_2O_3 content may increase to 40%-50%. It should be added that the "ageing" of laterite is commonly accelerated in Burma before it is used for road making and small blocks are often made up of friable masses.

Laterite is never found on mountains or

Table 5

Partial total chemical analysis of laterite, % of sample dried at 105°C

Depth, cm	Ignition losses	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	P_2O_5	Total
90—100	9,39	51,02	18,10	19,71	0,66	0,17	0,28	99,9
240—250	9,53	56,61	16,10	13,57	0,76	0,32	0,15	97,0
380—400	9,94	56,79	18,36	14,18	0,67	0,41	0,10	100,5
380—400, Red matrix	9,44	44,13	21,64	22,70	0,79	2,15	0,12	101,0
380—400, White cells	8,45	67,00	17,71	4,04	0,27	0,15	0,10	98,0

Note: Comma represents decimal point.

Table 6

Partial total chemical analysis of lateritic soils, % of sample dried at 105°C

Profile No.	District	Depth, cm	Ignition losses	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	MnO	P_2O_5	SO_3	Total
7-A	Pegu, Pegu Yoma	0—12	3,88	71,19	20,25	2,35	0,15	0,34	0,03	0,008	0,43	98,69
		30—42	7,54	63,43	19,30	6,82	0,23	0,33	0,02	0,003	0,07	97,77
		72—84	6,79	63,74	18,54	7,48	0,13	0,33	0,02	0,001	0,24	97,27
		138—145	7,03	62,42	19,42	8.07	0.22	0,52	0,02	0,001	0,11	97,81
1-B	Insein, Pegu Yoma	0—12	2,06	90,86	3,70	0,86	0,69	0,05	N. det'd.	0,14	n. det'd.	94,31
		42—57	3,34	84,76	11,22	2,06	0,26	0,06	"	0,14	"	101,78
		72—87	3,15	73,42	14,15	8,27	0,40	0,07	"	0,09	"	99,56
		105—117	5,02	70,38	16,81	6,93	trace	0,07	"	0.06	"	99,27
		135—150	6,21	75,92	9,95	4,80	0,29	0,05	"		"	97,17
		160—175	4,71	73,77	12,68	6,97	trace	0,05	"	0,03	"	98,20
		205—220	5,29	74,39	16,15	4,56	0,33	0,05	"	0,06	"	100,78
		275—290	4,26	76,71	14,50	4,59	0,20	0,07	"	0,07	"	100,40
		360—375	5,59	74,06	14,79	5,11	0,15	0,08	"	0,06	"	99,84

Note: Comma represents decimal point.

Table 7

Analytical data for lateritic soils

Profile No.	District	Depth, cm	pH	Humus, %	C:N	Exchangeable cations, meq/100 g			Hydrolytic acidity, meq/100 g	Base saturation, %	Content of particle diameter <0.002 mm, %
						Ca	Mg	Total			
7-A	Pegu, Pegu Yoma	0—12	4,2	3,02	15,5	3,0	1,9	4,9	7,60	39,2	16,51
		30—40	3,8	1,44	8,2	1,2	1,7	2,9	11,74	20,0	36,04
		75—85	4,0	0,72	6,1	1,3	1,3	2,6	11,91	18,0	33,82
		140—150	4,1	0,70	7,3	0,7	1,9	2,6	13,32	16,3	32,93
402-K	Maubin, Delta	0—10	4,5	1,24	9,2	1,7	2,3	4,0	2,51	61,5	16,54
		20—30	4,8	0,89	10,8	0,8	0,6	1,4	4,59	23,3	31,60
		50—60	4,8	0,54	7,2	1,6	1,2	2,8	4,25	40,0	27,42
		150—160	4,9	—	—	0,6	0,8	1,4	4,07	25,5	34,40
1-B	Insein, Pegu Yoma	0—12	4,7	1,18	12,1	2,2	1,2	3,4	4,24	44,9	7,90
		42—57	4,5	0,66	10,2	2,8	0,9	3,7	5,13	42,0	23,04
		72—87	4,5	0,28	8,4	2,0	0,8	2,8	5,28	35,1	23,62
		105—117	4,5	—	—	2,9	0,8	3,7	4,29	46,1	22,71
		135—150	4,7	—	—	2,3	1,2	3,5	6,38	34,5	25,63
		160—175	4,6	—	—	2,5	1,6	4,1	7,88	34,1	34,68
		205—220	4,5	0,07	—	2,0	1,2	3,2	7,98	29,0	33,20
		275—290	4,5	—	—	2,8	0,9	3,7	8,97	29,3	33,91
		350—375	4,5	—	—	2,5	0,8	3,3	9,87	25,0	41,12

Note: Comma represents decimal point.

mountain slopes in Burma. This would seem to throw some doubt on the classification of "mountain laterites" made by some authors.

Laterites forms at the foot of gentle hill slopes or slight rises of the order of 200 m-50 m of lowland plains, and is never found at altidudes of higher than 100 m-150 m above sea level in Burma. The only exceptions are two flat marshy basins of lacustrine origin in the Shan highlands, which are edged by lateritized soil.

In Burma laterites form either on Tertiary clay shales and sandstones in Pegu Yoma or on more ancient phyllites, granites, and gneissose granites in Tenasserim.

Lateritic soils are soils that develop on a laterite weathering crust or on laterite. It is not possible to classify all soils with some degree of allitization as lateritic soils although this is often done in the literature. In such a grouping all the red earths, red-brown forest soils, and certain other soils have to be combined with lateritic soils although their properties do not show any common features.

The structure of a typical lateritic soil profile is as follows. The soil layer itself is approximately 100 cm-120 cm thick and consists of an upper humified yellow-gray A horizon 15 cm-25 cm thick and underlying it a yellow, brownish-yellow, or grayish-yellow homogeneous B horizon. Below this there is a layer of pisolitic laterite 50 cm-100 cm thick that gives way gradually at a depth of 150 cm-200 cm to vermicular laterite which is several meters and sometimes as much as 10 m-50 m thick.

Total chemical analysis (Table 6) clearly reveals the relative enrichment of the surface horizon of these soils with silicic acid and the corresponding reduction in sesquioxides. Distribution of the clay content throughout the profile matches the sesquioxide distribution, i. e., texture is coarse in the surface horizon and clay formation is greatest in the lower part of the profile. Lateritic soils differ from yellow-brown and red-brown forest soils in that clay formation is greatest considerably below the center of the profile in the B horizon, i. e., in the vermicular laterite beneath the soil horizon.

The distribution of soil acidity throughout the profile is a distinguishing feature of lateritic soils (Table 7). It is only in lateritic soils that there is a gradual increase in hydrolytic and exchange acidity down the profile -- the reverse being the case in all other soil groups. Even in lateritized red earths and sierozems or in lateritic-gley soils acidity is increased in the lower part of the profile. There is a corresponding slight decrease in pH. A strongly acid reaction is a typical feature and adsorption capacity is not large. Base saturation varies between 40% and 60% in the upper horizon and gradually decreases with depth as acidity increases.

Lateritic soils are widely used for rubber plantations. Fruit crops do not do as well as on the thick red-brown or yellow-brown forest soils because of the nature of the root system of the plant which fails to penetrate the laterite layer.

Mention should also be made of the existence of a group of meadow, bog and alluvial river valley, and delta soils that are of great

Table 8

Analytical data for mangrove forest soils[a]

Profile No.	District	Depth, cm	pH	Humus, %	C:N	Exchangeable cations, meq/100 g			Hydrolytic acidity, meq/100 g	Base saturation, %		Content of particle diameters <0. 002 mm, %
						Ca	Mg	Total		P_2O_5	K_2O	
418-K	Myaung-mya, Delta	0—8	5,7	8,57	16,6	22,3	21.4	43,7	0,167	12,7	15,2	32,60
		15—20	5,6	2,92	8.7	8,1	20.4	28,5	0,162	7,9	7,9	37,90
		35—45	5,6	1,73	7,5	7,2	23,4	30,4	0,453	6,4	6,4	35,80
		60—70	6,1	—	—	3.6	17,8	21,4	0,527	—	—	32,95
		125—135	6,5	—	—	—	—	—	0,643	—	—	29,55
701-K	Papun, Delta	0—10	5,6	3,23	15,7	12,6	31,0	43,6	4,344	5,3	12,2	42,00
		25—35	6,2	1,46	14,2	5,3	15,2	20,5	1,071	8,9	8,4	40,00
		92—105	6,3	0,51	7,3	5,3	18,5	23,8	0,529	6,6	6,4	35,90
218-K	Papun, Delta	0—10	4,5	4,10	9,7	10,8	18,9	29,7	1,300	14,5	11,6	33,95
		25—35	6,2	1,44	7,0	4,5	18.2	22,7	0,325	12,3	7,0	40,00
		77—85	6,0	1,11	5,4	2,5	21,4	23,9	0,330	10,0	—	36,30

[a] Truog's method was used to determine the content of available forms of phosphorus. Available potassium compounds were determined by Aleksandrov's method in 1 N NaCl extract. Humus was determined by Knop's method.

Note: Comma represents decimal point.

agricultural importance. The majority of these soils have been greatly altered by cultivation since the commercial production of rice began in Burma a century ago. They have already been dealt with to some extent in the literature (5) and will not be further examined here.

The mangrove forest soils that are widely distributed along the Burmese seaboard are distinctive. There are two main types of mangrove forest, one of which is rhizophorous and is inundated daily by the tide and the other of which is only inundated by periodic high tides. In the first and narrower coastal strip the soil is a saline sticky clay that is constantly saturated by sea water. The second belt contains true soil profiles that can be divided into genetic horizons. The salinization of these soils decreases gradually as the distance from the shore increases. All the soils are strongly gleyed. These soils because of their striking content of humus and available nutrients are highly suitable for rice. Clearing forests and a little diking are all that is necessary to lower their salinization quite rapidly and yield excellent results.

These soils differ in salt regime (Table 8) but in general it can be said that they have evolved by gradual desalinization as result of continual and rapid accumulation of dry land and retreat of the sea. The distinctive feature of mangrove soils is that they are much richer in magnesium than calcium compounds.

This account of the main genetic soil groups in the humid monsoon tropical zone of Burma does not of course exhaust the diversity of the soil, especially since there has been scarcely any description of the various subgroups, genera, and species; this would be impossible in a single article, even if it were not the first description of the soils of Burma as a whole. All that has been attempted is to describe the dominant basic soil groups that determine the landscape of the zone.

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HUMUS AND ITS ROLE IN THE GENESIS OF CERTAIN TROPICAL AND SUBTROPICAL SOILS OF CHINA

TU MEN-CHAO, V. V. Dokuchayev Soil Institute, Forestry Laboratory, USSR Academy of Sciences

The composition of the mineral part of the soil has in the past attracted most attention in studies of the genesis of tropical and subtropical soils in general and especially in China. Particular significance has been attached to the $SiO_2:R_2O_3$ ratio as an index of the weathering of the soil-forming parent materials and of the development of the process of lateritization or allitization in the soils.

Least attention has been paid to the composition of the humus, its relationship to vegetation, the conditions under which it is decomposed and the interactions between the decomposition products and the mineral part of the soil.

This one sided approach to the genesis of tropical and subtropical soils was due to underestimating the part played by biological factors in tropical soil formation. A contributory factor here was the not entirely correct view that organic residues have little effect on the mineral part of the soil in the tropics owing to the rapidity of their decomposition and mineralization. The bright yellow and red colors of the soil were of no less importance since they led investigators to concentrate their attention on the total content of Al, Fe, and Mn and forms of their compounds as the indixes most likely to reveal differences in soil genesis.

The development of integrated (biogeocoenotic) studies of the soils and vegetation of the subtropical and tropical regions of China has meant that more and more attention has been paid to the composition and properties of humus and to the interactions between various types of vegetation and soils. This has arisen both because the extent of humus accumulation is one of the most important indixes of soil fertility and because its composition and properties can be used as an objective criterion for the explanation of soil genesis and for evolving a classification. These aspects have recently been studied by Zonn (11) and subsequently by Zonn and Li Cheng-Kvey (9) who have demonstrated that the basic differences in humus composition in the tropical and subtropical soils of China are related to the nature of the vegetation and to alteration in the climatic conditions governing decomposition (humid evergreen and deciduous forests, savannahs, and treeless expanses). U Dzhi-Khua (8) has described the composition of the humus of certain subtropical and chernozem soils. Nui ching Wên (6) has dealt with the nature and properties of humus in certain tropical and subtropical soils in south-western China (Yunnan Province) and in the northern part of Democratic Viet-Nam.

My object was to study the composition and forms of association of humic matter in the most typical soils of the tropical and subtropical area of southwestern China (Yunnan Province) to reveal its relationship to the bioclimatic conditions of decomposition and to altitude gradients (vertical zoning). Some of the results obtained are given below.

Brief Description of Research Aims and Methods

Five soils collected by S. V. Zonn in the tropical and subtropical parts of Yunnan Province were selected for study. The following are soils formed under typical monsoon tropical conditions.

Profile 1. From the vicinity of Damulun on ground belonging to the biogeocoenotic station of the Chinese Academy of Sciences in the south of the Hsishangpanna Tai Autonomous chou, beneath evergreen humid tropical forest with ferns[1] 760 m above sea level. Soil is a tropical yellow over-mature yellow earth developed on a lateritized thick fine earth.

Profile XXXIV. From the vicinity of the Red River on the road to Ting Ping. Vegetation of savannah type possibly secondary, after the thinning and cutting of tropical deciduous (dry) forests. Altitude 280 m. Soil cinnamon-brown -- red earth developed on the clayey eluvium of limestones.

Soils formed under the following conditions were selected from the humid tropical zone.

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[1] Described in greater detail by Zonn and Li Cheng-Kvey (10)

Table 1

Some climatic indixes for southwestern Yunnan

Place	Zone	Precipitation			Evaporation			Mean temperature °C			Relative humidity, %
		мм									
		V—IX	X—V	Annual	VI—X	X—V	Annual	V—IX	X—V	Annual	
Damulun	Tropical humid	938,6	152,2	1234,1	None			27,2	20,8	23,9	None
Red river	Tropical dry	547.8	226,8	774,6	889	1128	2017	27,7	22,5	24,3	65
Nanoshan	Subtropical	986,5	468,4	1454,9	424	991	1415	21,0	18,0	18,9	75

Note: Comma represents decimal point.

Profile XXXV. From the vicinity of Kedzu on a flat-topped limestone ridge. Now covered by fine grasses with remains of humid subtropical forests. Altitude 1340 m. Lateritic soil with concretions developed on old alluvial deposits underlain by limestones.

Profile XVIII. Subtropical yellow earth developed on granite eluvium from the vicinity of the Nanoshan ridge (near the Tea Experiment Station of the same name) beneath humid evergreen subtropical forest. Altitude 1790 m.

Profile XXX. Subtropical sierozem developed on gneiss eluvium at an altitude of 2200 m on a ridge near Ting Ping, (Southern Yunnan near the Laotian border) beneath evergreen moss forest with bamboo underbrush.

Table 2

Some indixes for the chemical composition of the soils

Profile No.	Depth, cm	pH of water suspension	Total content, % of ignited sample			Molecular ratios			Content of exchangeable cations, meq of absolutely dry soil				
			SiO_2	Al_2O_3	Fe_2O_3	$SiO_2:R_2O_3$	$SiO_2:Al_2O_3$	$SiO_2:Fe_2O_3$	Ca^{++}	Mg^{++}	H^+	Al^{+++}	Total
I	3—10	4,9	63,49	19,18	6,24	4,64	5,62	27,04	0,82	0,30	0,25	2,57	3,94
	15—25	4,9	61,20	21,32	6,86	4,04	4,87	23,70	0,35	0,30	0,17	3,41	4,23
	30—40	4,9	61,17	21,25	7,31	4,01	4,88	22,24	0,47	0,20	0,27	2,84	3,76
XXXIV	0—10	6,0	49,35	26,23	10,36	2,55	3,19	12,66	19,56	2,81	None		22,37
	20—30	6,3	52,29	24,49	9,57	2,90	3,63	14,53	19,98	2,35	"		22,33
	60—70	7,3	53,20	26,68	8,79	2,80	3,38	16,11	15,77	2,07	"		17,84
XXXV	2—10	6,8	51,36	20,90	12,67	3,08	4,17	11,79	8,34	1,27	None		9,61
	15—25	6,5	48,08	24,57	12,67	2,55	3,32	11,04	6,20	1,26	"		7,46
	70—80	6,0	44,51	28,09	14,54	2,02	2,69	8,14	4,16	0,90	"		5,06
XVIII	7—13	4,4	43,34	29,25	10,66	2,08	2,52	10,80	1,65	0,61	0,17	2,75	5,18
	20—30	4,4	42,79	31,45	11,18	1,88	2,31	10,18	1,19	0,30	0,17	2,29	3,95
	40—50	4,7	45,55	32,22	11,58	1,95	2,40	10,46	0,82	0,30	0,14	1,40	2,66
XXX	5—9	4,5	38,27	21,43	8,34	2,43	3,03	12,21	5,49	0,99	0,42	3,99	10,89
	10—18	4,4	43,79	21,48	12,57	2,53	3,47	9,34	1,67	0,46	0,35	3,62	6,10
	20—30	4,4	44,11	19,98	15,02	2,53	3,75	7,80	1,54	0,29	0,35	2,61	4,79

Note: Comma represents decimal point.

The last two soils differ from the first in having developed under conditions in which vertical zoning is clearly apparent in subtropical soil formation.[2]

Some of the climatic indixes of these districts are given in Table 1.

The conditions of humus formation differ fundamentally in each of these zones.

Although total annual precipitation is similar in the tropical and subtropical zones the former has a less humid dry season than the latter, in which annual precipitation is also higher; this indicates that conditions for the decomposition of organic residues are more favorable. Decomposition is also facilitated by the lower air temperatures in the subtropical zone (6°C lower than the tropical zone in the rainy season and 5°C lower in annual mean temperature).

In the dry tropical climate of the Red River valley temperatures are higher throughout the year and there is a marked reduction in precipitation and increase in evaporation.

The differences between the soils of the humid and dry tropics are most fundamental for some chemical properties (Table 2). The soil of the humid tropics (profile I) is acid, and has a reduced content of Al_2O_3 and Fe_2O_3 and a lower total exchangeable cations, among which Al predominates. The reaction (pH) of the soil of the dry tropics (profile XXXIV) varies from neutral to slightly alkaline (in the lower horizon) owing to the influence of the parent material. The Al_2O_3 and Fe_2O_3 content and the total exchangeable cations are higher. The exchangeable cations are Ca and Mg.

Soils of the humid subtropics with acid pH have a higher total exchangeable cations and a higher Al_2O_3 and Fe_2O_3 content (profiles XVIII and XXX) than do the soils of the humid tropics (profile I). The only soil that does not fit this generalization is that of profile XXXV that has a neutral reaction in the A horizon and a more acid reaction and corresponding alteration in the content of exchangeable Ca and Mg in the lower horizons. It also contains the greatest amount of total Fe_2O_3, the quantity of which increases with depth. There are many iron concretions in the A horizon owing to precipitation of Fe by alkaline solutions carried by surface runoff from higher areas. It is mentioned in the literature (4) that Fe is precipitated from soil solutions as concretions and other formations when its content is more than 12%. It is highly probable that the

Table 3

Humus and nitrogen content in the soils

Profile No.	Soil and vegetation	Depth, cm	Humus[a] (C X 1.724)	Total N, % of soil weight	C : N
	Tropical				
I	Yellow earth beneath humid over-mature forest with fern. Altitude 760 m	3—10	3,21	0,20	9,30
		15—25	2,35	0,14	9,71
		30—40	1,91	0,12	9,25
XXXIV	Cinnamon-brown — red earth beneath deciduous (dry) forest. Altitude 280 m	0—10	4,38	0,32	7,94
		20—30	3,00	0,19	9,16
		35—45	1,55	0,21	4,29
		60—70			
	Subtropical				
XXXV	Lateritic soil with concretions beneath herbaceous vegetation. Altitude 1340 m	2—10	3,55	0,25	8,24
		15—25	1,81	0,17	6,18
		35—45	0,82	0,12	4,00
XVIII	Yellow earth beneath evergreen forest. Altitude 1790 m	7—13	8,48	0,33	14,91
		20—20	6,26	0,28	12,96
		40—50	1,78	0,16	6,50
XXX	Yellow earth beneath moss-bamboo evergreen forest. Altitude 2200 m	5—9	22,95	1,07	12,04
		10—18	14,56	—	—
		20—30	11,95	0,63	11,00

[a] Carbon content given in Table 4.
Note: Comma represents decimal point.

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[2] Chen' Shi-Syun' (2) mentions that vertical zoning of climate and vegetation is clearly revealed in Yunnan Province.

Table 4

Humus composition, % of total organic carbon in initial soil

Profile No.	Soil and vegetation	Depth, cm	Total organic C % of weight of soil	C of alcohol-benzol extract	C extracted on decalcification	C of humic acids				C of fulvic acids					C of soil residue	Hydrolyzable C 0. 5 - 1. 0 N	$C_h:C_f$
						By fractions											
						I	II	III	Total	Ia	I	II	III	Total			
I	Yellow earth beneath humid over-mature forest w/fern.	3—10	1,86	3,2	5,4	7,5	0	8,1	15,6	10,8	2,7	12,3	0,5	26,3	38,2	11,3	0,59
		15—25	1,36	3,7	6,6	10,3	5,2	8,1	23,5	12,5	2,2	10,3	0,7	25,7	31,7	8,8	0,91
		30—40	1,11	3,6	6,3	11,7	0	9,8	20,6	15,3	0,9	8,1	0,9	25,2	32,5	11,7	0,82
XXXIV	Cinnamon-brown-red earth beneath deciduous (dry) forest.	0—10	2,54	1,6	2,8	21,3	11,4	11,4	44,1	2,4	0	4,3	4,7	11,4	34,2	5,9	3,86
		20—30	1,74	1,7	1,2	13,2	25,3	14,9	53,4	2,8	0	5,2	5,2	13,2	24,8	5,7	4,04
		35—45	0,9	2,2	2,2	31,1	0	14,9	45,6	3,3	0	0	11,1	14,4	26,7	8,9	3,15
XXXV	Lateritic soil with concretion beneath herbaceous vegetation.	2—10	2,06	3,4	1,9	8,7	0	4,9	13,6	10,7	14,1	0	7,8	32,6	33,9	14,6	0,42
		15—25	1,05	2,9	2,9	6,7	0,9	4,8	12,4	14,3	14,3	0	2,9	31,4	33,3	17,1	0,39
		35—45	0,48	2,1	2,1	2,1	0	6,2	8,3	18,7	4,2	2,1	6,2	31,2	39,6	16,7	0,27
XVIII	Yellow beneath evergreen forest.	7—13	4,92	4,1	3,5	16,7	0	7,1	23,8	7,9	2,9	12,6	0,6	24,0	36,9	7,7	0,99
		20—30	3,63	3,6	3,6	17,6	0	10,5	28,1	10,7	10,5	0	0,6	21,8	36,0	6,9	1,29
		40—50	1,03	1,9	5,8	8,7	0	6,8	15,5	14,5	1,0	7,8	1,0	24,3	40,8	11,7	0,64
XXX	Yellow earth beneath moss-bamboo evergreen forest.	5—9	13,31	5,8	2,3	15,4	0	5,6	21,0	0	24,3	0,8	5,9	31,0	33,1	6,8	0,68
		10—18	8,45	5,3	3,4	10,2	0	7,2	17,4	5,2	24,0	0	4,4	33,6	31,4	8,9	0,52
		20—30	6,93	5,5	4,0	10,0	0	4,9	14,9	20,4	6,3	0	8,8	35,5	26,7	13,4	0,42

Note: Comma represents decimal point.

concretions in this soil were formed in this way. There are no marked differences between the soils in pH and SiO_2 and Fe_2O_3 content. The clearest differences are in the composition and content of exchangeable cations, probably as a result of the composition of the vegetation and the conditions under which humus accumulated.

The following indixes were studied for humus: humus content (determined by Tyurin's method) and total nitrogen content (Kjeldahl); group and fraction composition of humus (Tyurin's outline); humus compounds combined with Fe and Al (determined by Aleksandrova's method [1]) and optical density of the humic acids (by Kononova's method [5]).

Amount and Composition of the Humus

Data for the amount and distribution of humus, nitrogen, and C:N ratio in the soils (Table 3) show that considerably less humus and nitrogen accumulates under humid tropical conditions (profile I) than under dry tropical conditions (profile XXXIV). Similarly the C:N ratio is wider in the former than in the latter. The reasons for such an alteration are associated both with the composition of the mineral part of the soil and with the nature of organic conversion at the surface. According to Zonn and Li Cheng-Kvey (10) up to 80% of the litter is decomposed in the forest in which Profile I was excavated during the rainy season. Nevertheless humus content does not exceed 3.2% in the upper horizon. It is probable that most of the decomposition products from the litter are washed from the profile. That this washing is not a marked feature of the cinnamon-brown; red earths are indicated by the fact that there is a marked decline in humus content with depth. In these soils the humus is largely combined with the mineral part of the soil due to the increased content of Ca and Mg. The C:N ratio is also increased. Humus accumulates more in the soils of the subtropical zone than in those of the tropical zone. There is also an increase in the thickness of the layer of active humus accumulation despite the low content of exchangeable Ca and Mg in the soil (profiles XVIII and XXX). The C:N ratio is subject to wide fluctuation.

Composition of the humus compounds. (Table 4). There are two distinct types of humus formation under tropical conditions. The first is humate-fulvate formation in soils beneath humid tropical evergreen forests. In these soils the ratio of C of the humic acids to C of the fulvic acids varies from 0.59 in the upper part of the humus profile to 0.91-0.82 in the lower part. Such change in the ratio would appear to indicate that there has been movement of the humic acids through the profile. This is particularly emphasized by the distribution of fractions I and III of the humic acids. The distribution of the fulvic acids indicates that only fraction Ia and part of fraction III have been subject to any considerable outwashing. Fractions I and II on the other hand are less available; they accumulate in the upper 25 cm of the soil and are probably combined with the sesquioxides of Fe and Al. The considerable content of hydrolyzed carbon and the low carbon content of the soil residue also confirm that the humus compounds are highly mobile because of outwashing and consumption by micro-organisms and animals (especially termites). The relatively high percentage of carbon, extracted by alcohol-benzol, in the composition of the humus is most probably associated with the increased amount of tannins and similar substances in evergreen leaves. It is not yet clear why the amount of carbon extracted by decalcification should be relatively higher than in other soils.

The second type of humus formation is humate formation. This occurs in soils beneath dry deciduous tropical forests developed both on carbonate and noncarbonate parent materials. According to Zonn and Li Cheng-Kvey (9) the ratio of C of the humic acids to C of the fulvic acids is greater than 2 in soils formed on noncarbonate parent materials. On carbonates it increases to 4.04 by reason of the predominance of humic acids (up to 53.4%) over fulvic acids (11%-14%) in the composition of the humus.

The humic acids that are most subject to movement are fraction I and, in part, fraction III. Fraction II is leached only from the upper 20 cm of soil and accumulates in the A_1 horizon at a depth of 20 cm-30 cm. The most mobile of the fulvic acids is fraction II some of which moves to a depth of 35 cm-45 cm. It therefore follows that it is mainly brown humic acids that are mobile in soils of this type. Ca humates are also partly mobile and this points to their known instability. It would appear from the even lower content of hydrolyzed carbon and of carbon in the soil residue that accumulation of mobile humus compounds predominates. This is also revealed by the low quantity of carbon extracted by alcohol-benzol and given off by decalcification.

One possible reason for the accumulation of free brown humic acids is the lower content of mobile Fe and Al compounds in these soils. Denisov (3) and others have shown that they may be transformed into oxides that are only slightly soluble when the soil is dry for long periods and soil temperatures are high.

The composition of the humus is more varied in the soils of the humid subtropics owing to alteration in the bioclimatic conditions under which plant residues are decomposed and to the composition of the mineral part of the soil. A more acid fulvate humus in which the ratio of C of the humic acids of C of the fulvic acids ranges from 0.42 in the upper horizon to 0.27 in the lower horizon is formed beneath herbaceous vegetation. Fulvic acids of fraction Ia and humic acids of fraction III are formed in the largest quantities in these soils and are most subject to movement. Only small quantitites of the remaining fractions of these and other acids are present and there are no clear distribution features. The content of hydrolyzed carbon is strikingly high (from 14.6% to 17.1%); this distinguishes the soil from all the other soils. It is highly probable that this fraction owes its presence to its combination with less readily soluble iron compounds formed on the precipitation of iron as concretions. The carbon yielded and XXX) have a higher accumulation of humic acids in the upper horizons than does the soil beneath tropical forest and subtropical herbaceous vegetation, as noted by Zonn and Li Cheng-Kvey (10, 11). Humic acids decrease and fulvic acids increase with altitude as the nature of the vegetation and especially the ground cover changes. Thus, whereas the ratio of carbon in the humic acids to carbon in the fulvic acids in the soil varies from 0.99-1.29 to 0.64 at 1780 m its variation through the profile at 2200 m is from 0.68 to 0.42. In both cases the ratio decreases with depth.

The soils differ from the soil beneath tropical forest in that the dominant fraction of the humic acids is fraction I, especially in the upper horizons. The content of fraction III is slight and it has no clear distribution pattern throughout the profiles. In the fulvic acids fraction Ia predominates over all the others in the soil at an altitude of 1790 m (profile XVIII) and its distribution indicates that it has been leached into the lower horizons. The increased content of fraction II combined with Ca in the A horizon is a striking feature of this soil.

Fraction Ia is even more mobile in the soil at an altitude of 2200 m (profile XXX) where it accumulates in the B horizon (20 cm-30 cm).

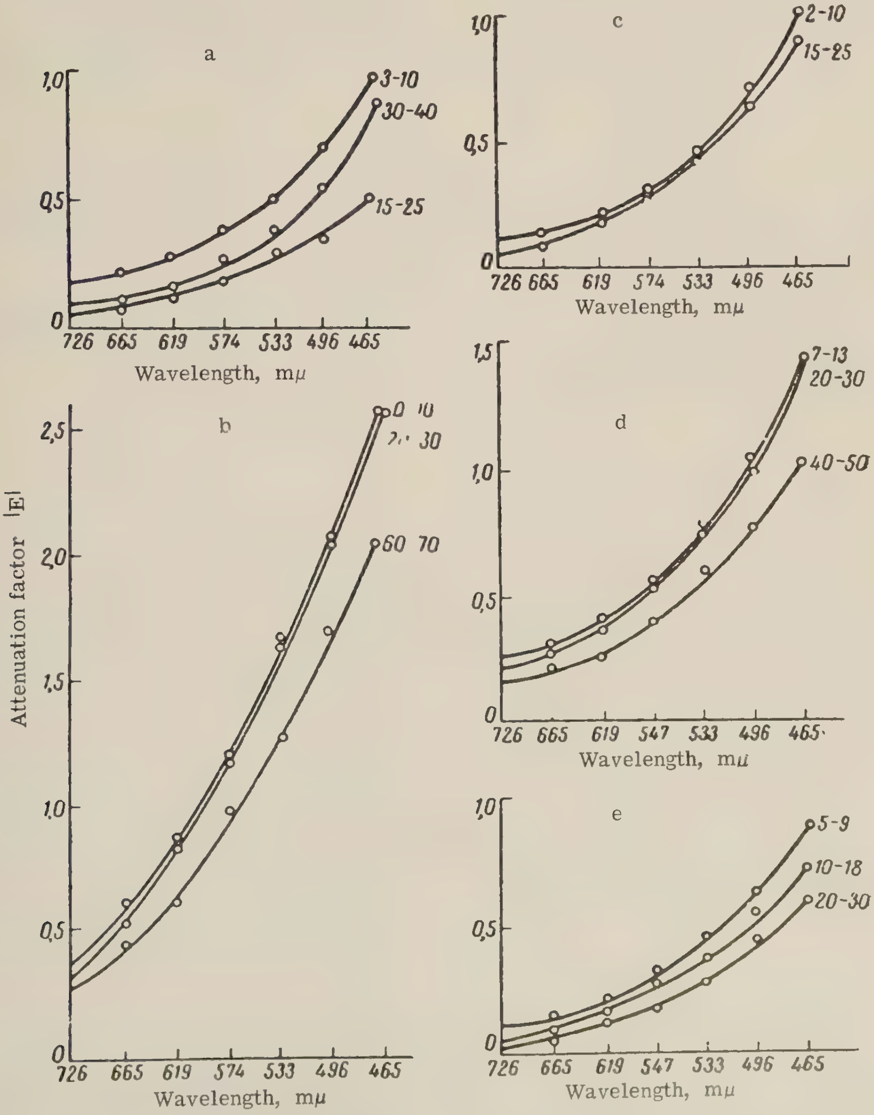

Fig. 1. - Optical Density of Humic Acids.
a - tropical yellow earth; b - tropical cinnamon-brown -- red-earth; c - lateritic soil with concretions; d - yellow earth, altitude 1740 m; e - yellow earth, altitude 2200 m. The values on the curves show the depth in centimeters.

Fraction I predominates in the A horizon. There is an increased content of fraction III in the same horizons and a clear tendency to move to the B horizon.

In general the mobility of soluble and hydrolyzed compounds increases with the rise in altitude under subtropical conditions and the content of humins decreases. The predominance of brown humic and fulvic acids in the composition of the humus makes these soils somewhat similar to brown forest soils.

Humus formation beneath typical subtropical forests differs from the preceding soils in that it may be classified either as of brown humate type without moss (profile XVIII) or as brown fulvate type with mosses and bamboo (profile XXX). The difference may be associated with the nature of the vegetation, but the question needs further study.

Optical Density of Humic Acids as an Index of Difference in their Nature

Optical density was studied in humic acid preparations extracted with 0. 1 N NaOH after decalcification; they were used to produce solutions of Na humates containing equal amounts of carbon (0. 136 g of carbon to 1 liter of solution) with a near neutral reaction.[3]

The results confirm the distinctions stated previously and indicate that there are fundamental changes in the optical density of humic acids formed in humid and in dry tropical climates. Under humid conditions the extinction coefficient is low in the A horizon and is considerably reduced with depth. Under dry conditions (Fig. 1b for cinnamon brown – red earth) the extinction coefficient is 2. 5 times greater and considerably less reduced with depth.

Under subtropical conditions the optical density of humic acids from a lateritic soils containing concretions (Fig. 1c) is similar to that of a tropical yellow earth (Fig. 1d) and subject little to change with depth. It is 1. 5 times greater in a yellow earth at an altitude of 1790 m (Fig. 1e) and only approximates to the first soil at a depth of 40 cm-50 cm. The lowest optical density (<1)[4] is found with humic acids from the yellow earth at an altidude of 2200 m (Fig. 1e).

It is possible that alterations in the optical density of humic acids of tropical soils are due to differences in moisture conditions as suggested by Kononova (5) and Tyurin (7). Under dry conditions humic acids have a more highly condensed aromatic nucleus similar to the nucleus in chernozems.

In addition to differences in moisture conditions, increase and decrease in the optical density

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[3] The layer of solution in the spectrophotometer vessels was 1 cm. The optical density of the humic acids was determined in the laboratory of Soil Biochemistry and Biology at the V.V. Dokuchayev Soil Institute.

[4] In the blue range at 465 mμ.

Table 5

Amount of C, Fe and Al extracted from the soils by an 0. 1 M solution of $Na_4P_2O_7$, mg per 100 g of soil

Profile No.	Soil and vegetation	Depth, cm	C	Fe	Al
I	Yellow earth beneath humid over-mature forest with fern	3—10 15—25 30—40	580 500 450	166 432 432	1067 2155 1046
XXXIV	Cinnamon brown — red earth beneath deciduous (dry) forest	0—10 20—30 35—45	790 680 310	67 67 66	507 265 249
XXXV	Lateritic soil with concretions beneath herbaceous vegetation	2—10 15—25 35—45	500 300 170	233 200 267	1144 774 871
XVIII	Yellow earth beneath evergreen forest	7—13 20—30 40—50	196 156 430	872 773 399	5106 5127 1745
XXX	Yellow earth beneath moss-bamboo evergreen forest	5—9 10—18 20—30	435 325 316	797 795 1003	7317 4858 8516

of humic acids in subtropical soils may also be associated with the influence on their structure of special features in the mineral part of the soil. The low optical density of the humic acids of tropical soils is due to their "chemical youthfulness" (6), which in its turn is connected with special features in humus formation and especially the predominance of brown humic acids.

Connection Between Humic Compounds with Iron and Aluminum

In view of the high iron and aluminum content of tropical and subtropical soils it is through that alumino- and ferro-humic compounds account for a large part of their humic matter. Extraction methods do not exist that would enable us to establish the quantities of these compounds in different soils. We separated them by solution in an 0.1 m solution of sodium pyrophosphate (Aleksandrova's method). The results of the determinations are shown in Table 5.[5]

The values obtained show that considerably larger quantities of aluminum, iron, and organic matter pass into an 0.1 m solution of pyrophosphate from tropical soils formed under humid conditions (profile I) than from those formed under dry conditions. It would also appear from the amount of carbon that most of the humic compounds in the first group of soils are combined with Fe and Al; in the second group free humic acids probably predominate. This distinction agrees with the fact that the mobility of Fe and Al compounds is reduced in a prolonged dry season owing to their conversion to oxides that are not readily soluble.

The quantity of these compounds in subtropical soils increases markedly with altitude owing to the reduction in temperature and possibly to increased moisture. Since the increase particularly affects the amount of Al_2O_3 it can be assumed that there are more alumino-humic than ferro-humic compounds in subtropical soils and that free humic acids are absent. This latter fact may be due to the absence of podzolization in these soils.

The reduction in the amounts of C, Al_2O_3, and Fe_2O_3 that pass into an 0.1 m solution of sodium pyrophosphates from lateritic soil is probably due to their precipitation in the formation of concretions.

It should be emphasized that these indixes for podzols differ greatly from the values obtained for our soils as can be seen from the following data (1) (milligrams per 100 g):

Depth, cm	C	Al_2O_3	Fe_2O_3
5–9	666	159	169
9–22	112	50	69
41–61	48	45	86

Sodium pyrophosphate extracts up to 53%-70% of the total content of carbon from tropical soils and slightly more from subtropical soils, but there are great variations in the amount of carbon. Thus, only 41%-61% is extracted from lateritic soils (profile XXXV), 68%-74% from yellow earths at an altitude of 1790 m (profile XVIII) and 56%-78% of total content at an altitude of 2200 m. The mobility of the humus compounds increases with altitude since the highest values are those of their content in the lower horizons. This is particularly marked in the soil of profile XXX; here there is a sharp increase in the amount of Al_2O_3 and Fe_2O_3 with depth. These distinctions are most vividly revealed by the values for mobile Al_2O_3 and Fe_2O_3 calculated as percentages of total content;

Profile	Fe_2O_3	Al_2O_3
I	2.66–6.21	4.92–10.11
XXXIV	0.65–0.70	1.51– 1.08
XXXV	1.58–1.84	3.15– 5.47
XXVIII	3.45–8.22	5.42–17.46
XXX	6.32–9.51	22.62–34.14

These values are the least in tropical soils (profile I and XXXIV and lateritic subtropical [profile XXXV]). They sharply increase in the remaining soils, particularly with increased altitude.

The information here given can be used to correct the previous types of humus formation and to give the following definitions:

Humid Tropical Soils	Humate — fulvate (profile I)
Dry tropical soils	Free humate (profile XXXV)
Subtropical humid: lateritic soils	Acid fulvate-iron-alumino (profile XXXV)
yellow earths up to an altitude of 1800 m	humate-alumino-iron (profile XVIII)
yellow earths at between 1800 m and 2200 m	humate-iron-alumino (profile XXX)

These names are intended merely to depict the most apparent distinctions in the types of humus formation and are quite tentative. Nevertheless the classification may be of use for further work on the genesis and classification of tropical and subtropical soils.

Conclusions

1. The accumulation of humus and nitrogen is lowest in humid tropical conditions and does not exceed 4.38%. In dry tropical conditions it is higher and uniform throughout the profile. The C:N ratio is wider under humid tropical conditions.

The humus and nitrogen content of subtropical soils increased with altitude.

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[5] It should be remembered that sodium pyrophosphate extracts a certain amount of nonsilicate forms of R_2O_3 that combine with the solvent to form complex compounds in addition to humic matter combined with Fe and Al from soils of this type. It cannot therefore be concluded that the organic matter in an 0.1 M $Na_4P_2O_7$ extract is only complex compounds with R_2O_3.

2. The following five types of humus formation are derived from the group and fractional composition of the humus, the optical density of the humic acids and the content of free humic acids and humic acids combined with Fe and Al:

a) humate-fulvate in soils beneath humid evergreen forests;

b) free humate in soils beneath dry deciduous tropical forests.

In the humid subtropics:

a) acid-fulvate-iron-alumina in lateritic soils beneath herbaceous vegetation;

b) humate-alumino-iron in yellow earth beneath evergreen forests up to 1800 m; and

c) humate-iron-alumina in yellow earth beneath evergreen moss forests above 1800 m.

These types of humus formation are a clearer indication of differences in soil genesis than are the $SiO_2:Al_2O_3$ and $SiO_2:Fe_2O_3$ ratios.

This study was supervised by Professor S. V. Zonn in the Forestry Laboratory of the USSR Academy of Sciences. The author thanks his supervisor and D. F. Sokolov for assistance in carrying out the work and writing up the results.

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THE SOILS OF NORTH AMERICA - A GENERAL DESCRIPTION (Based on Materials Presented at the VII International Congress of Soil Science)

N. N. ROZOV, YE. B. RUBILIN, and YE. N. RUDNEVA, V. V. Dokuchayev Soil Institute

Study of the soils of North America has had very great bearing on the correct interpretation of soil zoning, clarification of the essential nature of the processes of soil formation, and the scope of views on the problem of soil classification.

Dokuchayev's assumption that only latitudinal soil zones existed in North America was reflected in his projected soil zones of the Northern Hemisphere. Direct study of the soils of North America has revealed that the soil zones are meridional in the southern monsoon region. Soviet scientists made their first acquaintance with the soils of the USA and Canada during the First International Congress of Soil Science in 1927. Materials on the soil geography of North America obtained at the Congress and during an extensive transcontinental excursion were critically reviewed in works by I. V. Tyurin,[1] D. G. Vilenskiy[2] and Ya. N. Afanas'yev.[3]

Tyurin gave a detailed description of soils encountered during the excursion accompanied by analytical data. He was one of the first to stress the meridional nature of soil zoning in the USA and the influence of men in the formation of the prairie soils.

Vilenskiy and Afanas'yev paid a great deal of attention to the distinctive conditions of soil formation and the general features of geographical distribution and soil classification. They commented repeatedly on the diversity of soil-forming processes and soils in North America and made a detailed analysis of the work of Marbut. In their final conclusions and in their soil maps they attempted to draw a complete analogy between the soils of North America and those of the Russian Plain and, in part, the West Siberian lowland.

The specific features of soil formation in the monsoon and subtropical regions were only noted later when Prasolov[4] recognized that the prairie soils were a separate entity distinct from the chernozem and when Vilenskiy, who was developing the idea of analogous subtypes, noted the distinctive nature of the soils in the subtropical areas of North America. These features were only incorporated in the world soil classification after a zonal subtype consisting of cinnamon brown, gray-cinnamon-brown, and sierozem soils had been distinguished as a specific subtropical sub-type in Eurasia.

This new outlook on the soil geography of North America, which is especially reflected in the most recent edition of the world soil map, leads to the assumption that North American soils ascribed to the same soil groups as Soviet soils and are partly represented by other subgroups.

New material on the geography and genesis of United States soils was obtained at the Seventh International Congress of Soil Science held at Madison, Wisconsin, in the United States and during the excursions organized by the Congress; there was an opportunity to verify, in part, existing scientific views.

The major soil excursion in 1927 was a circular tour that crossed the North American continent twice from ocean to ocean and included Canada. The routes of the three soil excursions in 1960 lay mainly within this circle (within the USA) and only one excursion extended to the southwest outside the circle including New Mexico and Arizona (Fig. 1).

The soil material collected during the excursions was not very extensive (no more than 50 profiles were examined in all three excursions). The existing quarantine regulations prevented the taking of soil samples but the main analytical data were normally quoted in the guides. "Soil classification, a comprehensive system" written by Guy Smith, one of the heads of the Soil Conservation Service, and distributed to all congress participants was of great help. It contained descriptions and analyses of approximately 100 profiles of

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[1] The soils of North America. Uch. Zap. Kaz. gos. un-ta, vol. 88, Pt. 1, 1928.

[2] Principal features to the distribution of the soils and vegetation of the USA and Canada. Pochvovedeniye, 1928. No. 1-2.

[3] The soil zones of North America. Pochvovedeniye, 1928. No. 3-4.

[4] The Great Soviet World Atlas. 1937.

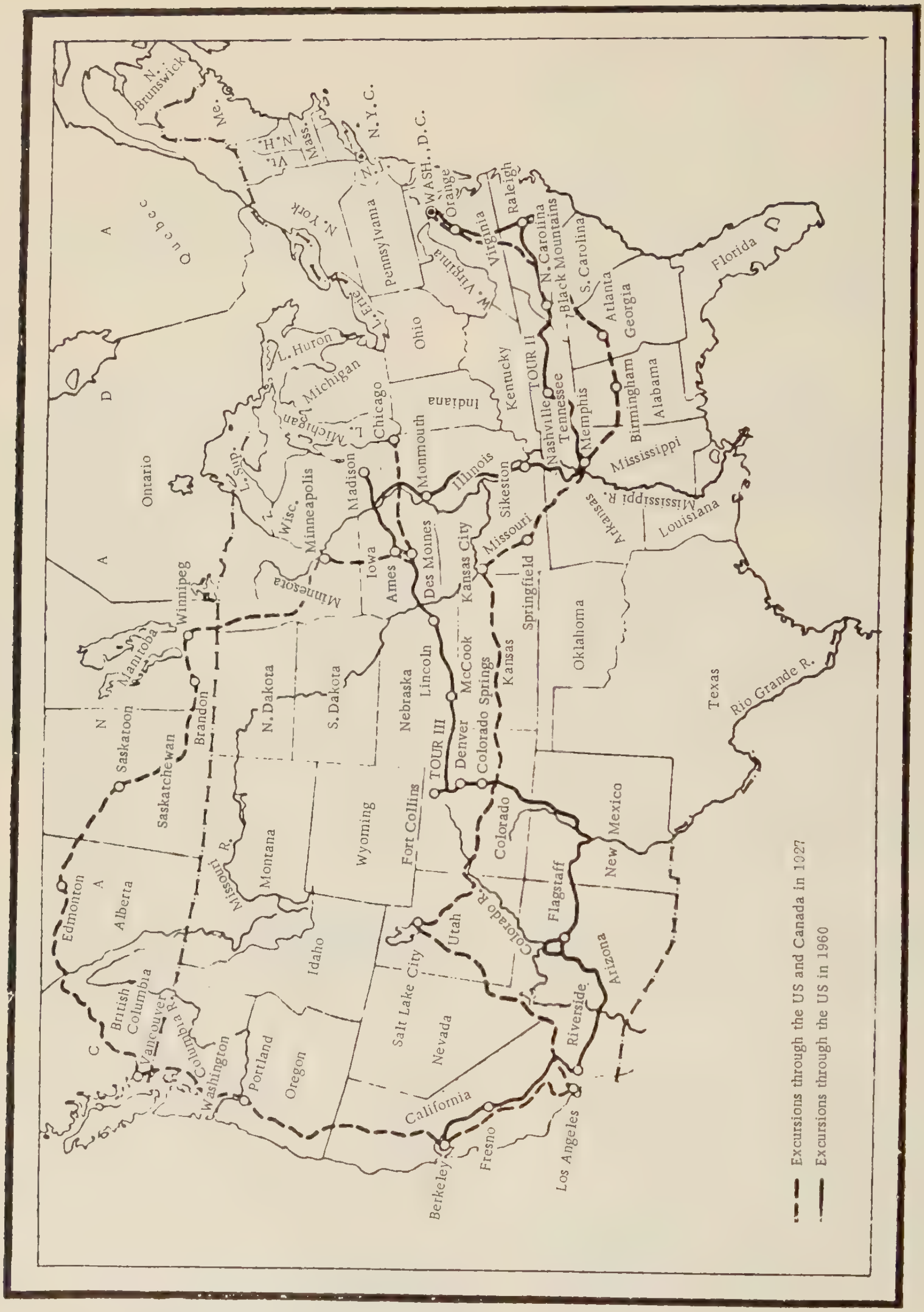

Fig. 1. - Routes of the excursions throug the United States.

the main taxonomic subdivisions of soils in the US with indication of their location.

We shall now deal briefly with the principal conclusions on the geography and genesis of the soils of the USA that can be derived from the materials of the Seventh International Congress of Soil Science, the excursions, and the existing references in the literature.[5]

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[5] The authors went on two of the excursions: Madison-San Francisco (Rozov and Rubilin) and Madison-

NORTH AMERICA

Little mention was made at the congress of the soils of the north of the North American continent -- Canada and Alaska. It was apparent from the paper of Douglas and Tedrow on the tundra soils of Alaska that cryogenic phenomena and frozen soil are extensively developed in the districts that they studied and that certain features are similar to the soils of our own far north east.

S. Pavliuk (Canada) gave a detailed description of the gray wooded soils of Alberta. These soils, that occupy extensive areas in the foothills of the Rockies and extend far to the north, are not uniform in their properties. Their southern variants beneath Populus tremuloides forests can be compared to some extent with our own gray forest soils; it would appear from the monoliths and analyses on display that the northern variants of these soils are most distinctive; they are peaty at the surface, highly podzolized, with a practically undeveloped platy A_1 horizon and a humus-stained A_2 horizon. They should probably be regarded as a special provincial species or subgroup of sod-podzolic soils developed under the comparatively dry conditions of Western Canada where the annual moisture coefficient (ratio of annual precipitation to annual evaporation. Translator) beneath coniferous forests is between 0. 99 and 0. 60.

It is common knowledge that the soil-geographical zoning of North America undergoes a marked change to the south of a line passing through Edmonton, Saskatchewan, Winnipeg and Lakes Superior and Huron. The soil zones become meridional and apparently intersect the subboreal, subtropical, and tropical belts, (down to the Gulf of Mexico) since they are naturally represented in each bioclimatic belt by their groups.

Within the subboreal soil belt one can distinguish: 1) a zone of brown forest soils, 2) a zone of chernozem-like prairie soils (brunizems), 3) a zone of chernozems, 4) a zone of chestnut soils, and 5) a zone of brown desertic-steppe soils.

The corresponding zones in the subtropical belt are: 1) a zone of red earths and yellow earths, 2) a zone of reddish-black prairie soils, 3) a zone of cinnamon-brown soils, 4) a zone of gray-cinnamonic soils, and 5) a zone of sierozems of various types.

The alternation of the vertical soil zones found in the mountains of North America is governed by the general features of bioclimatic zoning and the facies.

Those who attended the Seventh International Congress of Soil Science were able to cross the whole of the subboreal soil and bioclimatic belt from the Atlantic to the Rocky Mountains. The path of excursions ran mainly through the south of this belt between 42° and 36°N.

The brown forest soil zone occupies considerable areas to the south and south-west of the Great Lakes. It extends in a sweeping arc from the banks of Mississippi in the west to the Atlantic seaboard in the east for more than 1200 km.

The southern limit of these soils passes to the south of the Ohio River and coincides in places with the southern boundary of the Wisconsin glaciation. The main soil-forming parent materials are glacial and lacustrine-glacial clays, clay loams, and sands often covered by loesses. The natural vegetation beneath which the brown forest soils of the US form consists of broadleaf deciduous forests of red oak, (Quercus rubra), sugar maple (Acer saccharatum), American basewood, beech, and hornbeam. Species of hickory are often encountered in the south and southwest of the zone in forests of this type.

The considerable longitudinal (300 km-400 km) and latitudinal (1200 km-1400 km) extent of the zone makes for a variety of landscape and for the formation of different subgroups and species of brown forest soil on the North American continent.

In the eastern and more humid oceanic part of the zone (Fig. 2a, New York Station) one can expect to find extensive areas of acid deeply base-unsaturated slightly podzolized brown forest soils (Table 1, profile 1) with similar properties (acidity, unsaturation and composition of the organic matter) to the brown acid (forest) soils of Western Europe.

It is apparent that the brown forest soils of this part of the zone are also subject to considerable latitudinal alteration. Intensive podzolization becomes universal in the north where they give way to soddy, straw-colored-podzolic and sod-podzolic soils. In the south a general tendency for an increase in clay content is accompanied by certain slight signs of allitization in the profile of brown forest soils. This makes them closer to the yellow earths that lie further to the south and leads to the assumption that they are similar to the yellow-brown soils of Europe and China.

In the western part of the zone (Fig. 2a, Chicago Station) the great dryness of the summer and fall gives rise to brown podzolic forest soils with a more distinct podzolized horizon that are at the same time less acid, richer in adsorbed bases, and considerably less unsaturated (Table 1, profile 2).

In the north of this part of the zone, where the brown forest podzolic soils give way gradually to the gray forest soils of Canada (gray wooded soils) they are closer to the brown-gray forest soils of Romania, the northern slope of the Great Caucasian range and other European territories. The name gray-brown podzolic soils that is used in the USA for all brown forest soils seems to give a completely adequate description of the features of this last subgroup of brown forest soils.

Comparison of the data for brown forest soils of Western Europe and for the center and southwest of the North American brown forest

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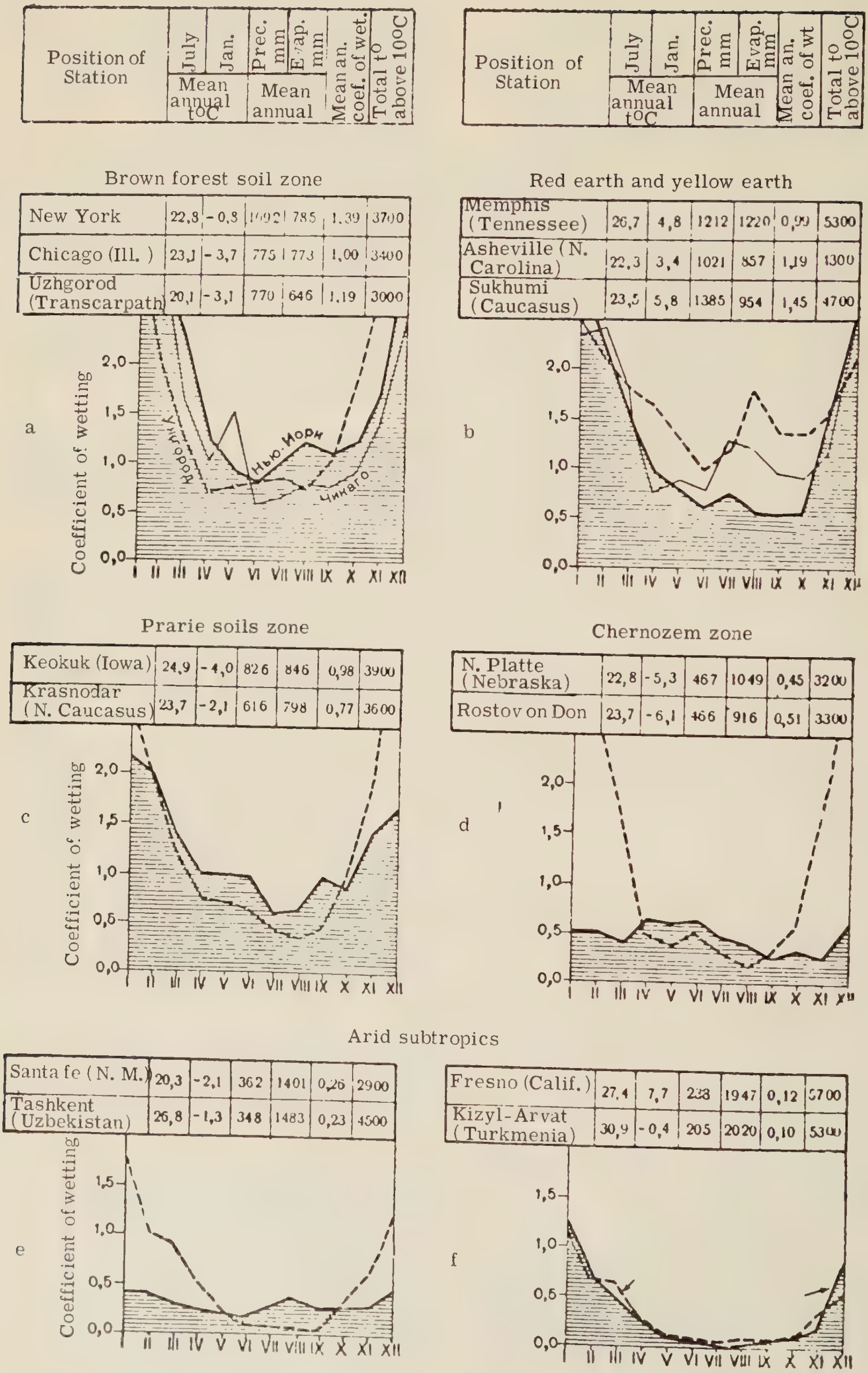
Washington (Rudneva). We wish to thank I.V. Tyurin for reading the article and for valuable comments.



Position of Station	July	Jan.	Prec. mm	Evap. mm	Mean an. coef. of wet.	Total t° above 10°C
	Mean annual t°C		Mean annual			

Brown forest soil zone

New York	22,8	- 0,8	1092	785	1,39	3700
Chicago (Ill.)	23,1	- 3,7	775	773	1,00	3400
Uzhgorod (Transcarpath	20,1	- 3,1	770	646	1,19	3000

Red earth and yellow earth

Memphis (Tennessee)	26,7	4,8	1212	1220	0,99	5300
Asheville (N. Carolina)	22,3	3,4	1021	857	1,19	1300
Sukhumi (Caucasus)	23,5	5,8	1385	954	1,45	4700

Prarie soils zone

Keokuk (Iowa)	24,9	- 4,0	826	846	0,98	3900
Krasnodar (N. Caucasus)	23,7	- 2,1	616	798	0,77	3600

Chernozem zone

N. Platte (Nebraska)	22,8	- 5,3	467	1049	0,45	3200
Rostov on Don	23,7	- 6,1	466	916	0,51	3300

Arid subtropics

Santa fe (N. M.)	20,3	- 2,1	362	1401	0,26	2900
Tashkent (Uzbekistan)	26,8	- 1,3	348	1483	0,23	4500
Fresno (Calif.)	27,4	7,7	238	1947	0,12	5700
Kizyl-Arvat (Turkmenia)	30,9	- 0,4	205	2020	0,10	5300

Fig. 2. - Climatic conditions for the formation of the main soil groups of the US compared with corresponding data for the USSR.

Table 1

Analytical description of the soils of broadleaf forests, prairies and humid subtropics of the US[a]

Profile No., soil, position, vegetation, and parent material	Depth, cm	pH water (1:1)	Clay <0.002 mm in dia.	Humus, %	$CaCO_3$, eq %	Adsorbed cations, meq/100 g						Unsaturation, %
						Ca	Mg	H[b]	Na	K	Total	
1. Brown podzolized forest soil (deeply unsaturated) New York; oak forest; glacial clay (Guy Smith)	0—10	5,4	10,8	5,50	None	7,9	1,8	13,1	0,1	0,3	23,2	56
	10—20	4,8	9.9	2,00	"	1,1	0,3	10,9	0,1	0,1	12,5	87
	20—41	5,2	8,4	0,65	"	0,9	0,2	5,4	0,1	0,1	6,7	81
	41—46	5,1	11,4	0,52	"	1,4	0,5	5,8	0,1	0,1	7,9	74
	46—53	5,4	16,0	0,61	"	2,7	1,2	6,4	0,1	0,1	10,5	62
	53—69	6,9	23,4	0,83	"	3,8	1,4	4,4	<0,1	0,1	<9,8	45
	69—107	8,0	7,8	0,17	31,4	—	—	—	—	—	—	—
	178—204	8,2	9,5	0,21	34,6	—	—	—	—	—	—	—
2. Brown podzolized forest soil Wisconsin; hickory-oak forests; loëss clay loam (guide to third excursion)	0—5	5,6	13,0	9,68	None	12,3	4,3	13,5	0,1	0,6	30,8	18
	5—23	5,0	13,5	1,14	"	1,2	0,7	8,4	0,1	0,2	10,6	71
	23—43	5,0	16,9	0,52	"	2,0	1,7	7,6	0,1	0,2	11,6	54
	43—60	5,0	23,8	0,34	"	4,9	2,9	9,2	0,1	0,3	17,4	38
	60—90	4,9	27,7	0,28	"	6,9	3,6	10,3	0,1	0,3	21,2	36
	90—108	5,0	30,7	0,29	"	10,2	5,0	9,0	0,1	0,4	24,7	21
	108—123	5,2	29,6	0,24	"	10,8	5,1	8,8	0,1	0,3	25,1	15
	123+	5,1	26,3	0,21	"	10,0	4,5	7,8	0,1	0,3	22,7	15
3. Illinois: tall grass prairie; loëss (guide to second excursion)	0—16	5,7	28,6	4,04	None	13,9	3,4	9,3	0,1	0,5	27,2	34
	16—28	5,8	32,2	3,35	"	13,8	4,2	11,4	0,1	0,4	29,9	38
	28—42	5,7	34,2	2,44	"	14,3	5,8	9,6	0,1	0,4	30,2	32
	42—51	5,8	35,6	1,67	"	14,6	6,4	8,5	0,1	0,4	30,0	28
	51—64	5,7	35,5	1,17	"	15,0	6,8	8,1	0,1	0,4	30,4	27
	64—74	5,7	33,2	0,77	"	14,7	6,6	7,6	0,1	0,3	29,3	26
	74—90	5,7	30,4	0,58	"	14,3	6,6	6,8	0,1	0,3	28,1	24
	90—115	5,8	28,2	0,36	"	14,4	5,8	6,1	0,1	0,3	26,7	23
	115—130	6,1	28,5	0,26	"	15,2	5,7	5,1	0,1	0,3	26,4	19
	130—156	6,5	27,6	0,21	<1	16,1	5,6	4,1	0,2	0,4	26,4	16
4. Iowa; plowed land; loëss, underlain by moraine (guide to third excursion)	0—32	5,2	23,7	6,07	None	17,4[c]		—	—	—	24,6	29
	32—47	—	29,1	3,77	"	14,5	4,6	—	—	—	26,4	28
	47—62	—	32,7	2,76	"	12,9	5,4	—	—	—	24,9	25
	62—72	5,4	34,5	1,65	"	21,2[d]		—	—	—	25,8	18
	72—88	—	34,8	0,98	"	22,7		—	—	—	25,9	12
	88—100	—	33,9	0,55	"	23,6		—	—	—	25,7	8
	100—150	—	30,0	0,34	"	21,6		—	—	—	22,3	3
	150—200	—	26,0	0,21	"	19,9		—	—	—	19,8	2
	200—285	7.5	18,9		"	16,4		—	—	—	16,2	0
5. Podzolized red earths (deeply unsaturated) Virginia; broadleaf forest; strongly weathered sericitic schist (guide to second excursion)	0—18	5,2	20,0	1,70	None	1,39	0,73	5,11	0,05	0,50	7,70	66
	18—25	5,5	46,7	0,72	"	0,79	0,40	9,54	0,04	0,31	11,08	86
	25—55	4,8	56,5	0,72	"	0,81	0,73	9,68	0,01	0,34	11,57	84
	55—80	5,0	55,4	0,19	"	0,08	0,39	10,09	0,02	0,38	10,96	92
	80—137	4,9	14,5	9,03	"	0,04	0,13	4,19	0,02	0,11	4,49	93

Table 1 Cont'd.

6. Podzolized red earth — Red-Yellow Podzolic soil (Umbric Typochrult); Tennessee; fruit orchard, limestone and shale deluvium (gd. to 2nd ex.)	0—15	5,8	19,2	2,7	None	8,0	1,0	9,3	0,1	1,1	18,5	48
	15—32	5,8	25,2	0,5	"	4,5	0,9	7,1	<0,1	0,6	13,2	54
	32—45	5,3	28,2	0,3	"	4,7	1,2	7,8	<0,1	0,3	14,1	56
	45—67	5,3	33,4	0,1	"	4,8	2,0	9,1	0,1	0,2	16,2	56
	67—102	5,2	38,5	0,1	"	3,6	1,9	11,2	0,1	0,2	17,0	64
	102—130	5,0	43,6	0,2	"	4,2	1,9	14,2	0,1	0,3	20,7	71
	130—160	4,7	45,4	0,1	"	2,3	1,4	16,9	0,1	0,3	21,0	80
	160—185	4,5	48,1	0,1	"	1,7	1,0	19,0	0,1	0,3	21,1	84
	185—212	4,3	50,9	0,2	"	0,8	0,6	21,0	0,1	0,2	22,7	92
	262—280	4,3	51,2	0,1	"	1,6	0,6	22,6	0,1	0,3	24,2	90

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[a] The names given to the soils are those of the nomenclature accepted in the USSR (where it differs from the American. Translator), the existing American nomenclature and that proposed by Guy Smith.

[b] Exchange acidity.

[c] Total of exchangeable bases.

Note: Comma represents decimal point.

soils zone reveals that the American soils are quite similar to the brown forest podzolized soils of Eastern Europe. On the other hand the brown forest soils of the center and west of the zone in the US are more podzolized and less ferruginized than the corresponding soils of Eastern Europe (the Transcarpathians).

The following features to the distribution of the soils in the North American brown forest soils zone are related to local formation conditions and the composition of the soil-forming parent material.

In the west and center of the zone where glacial clay loam deposits predominate, the predominant soil group is the brown forest podzolized soils (gray-brown podzolic soils). These soils occupy the best drained forested surfaces of hills and slopes. The levelled steppe-like sectors of slopes and plains consisting of loess-covered morainic clay loams are normally occupied by chernozem-like prairie soils (brunizem). Depressions and the less drained flattened and more moist lower sectors of slopes are often waterlogged and occupied by dark humic gley soils and swamp soils and by bottomland peats (peat soils).

In the southwest part of the zone not affected by glaciation combinations of a slightly different group are found in regions where loess deposits predominate. The dominant soil group on level areas is brunizem. Brown forest soils are confined to the steeper slopes. Depressions and low-lying areas are occupied by humic-gley and swamp soils and by soils that are transitional between humic-gley soils and brunizems. In the more humid eastern sector of the zone brown acid deeply unsaturated soils are accompanied by excessively moist and greatly podzolized soils and by soils that are similar to podzols and are mainly confined to parent materials of coarser-texture.

A zone of black prairie soils (brunizems) lies to the west of the brown forest soils zone. Its meridional extent is approximately 2000 km-2200 km and it is widest (approximately 800 km-900 km) at latitude 40° where a large wedge of brunizems extends to the left bank of the Mississippi River into the brown forest soils zone. The distinctive climatic conditions under which brunizems form have no analogy in the chernozem of the USSR. Temperature conditions make the climate in the central sector of this meridional zone (Keokuk Station, Iowa) similar to the climate at Krasnodar, but considerably more humid in the summer (Fig. 2c). This leads to the development of slight "climatic meadowing" features in the soils where drainage is normal.

Brunizems are formed beneath a lush vegetation of tall grass including Andropogon furcatus, A. geradi, A. Scoparius, and Stipa spartea and a rich assortment of grass (Astragalus crassiocarpus, Phlox pilosa, Anemone caroliniana, Viola pedata, Lathyrus sp., Solidago sp., etc.)

The soil profile of the brunizems, that normally form on loess-like and less frequently on morainic clay loams, consists of a 50 cm-60 cm humus horizon with a very gradual decline in humus, as in chernozems, and a transitional horizon to the soil-forming parent material with slight signs of gleying. Humus content varies between 4% and 6% from the surface down. Reaction is slightly acid (pH 5.4-6.1) and Ca and Mg are the major adsorbed cations; a high content of hydrogen ions is clearly due to the method of determining adsorbed cations using alkaline salts (Table 1, profile 3 and 4). Free calcium carbonate is either totally absent or found only in the second meter, mainly in residual forms. The white non-effervescing veinlets of SiO_2 often found at this depth were observed by delegates in one brunizem profile in Wisconsin. Despite the slightly acid reaction, signs of podzolization are either absent, not expressed or poorly expressed, mainly in the eastern part of the zone as silica powdering (see the distribution of the clay fraction in profile 3 and 4 in Table 1). On this basis brunizems can be divided into three subgroups, that might be called chernozem-

Table 2

Analytical description of the soils of the steppes, semideserts, and mountain forests of the US

Profile No., soil, position, vegetation, and parent material	Depth, cm	pH water (1:1)	Clay <0.002 mm in diam.	Humus, %	$CaCO_3$ eq. %	Adsorbed cations, meq/100 g					
						Ca	Mg	H[a]	Na	K	Total
7. Medium humus ("ordinary") chernozem — Chernozem (Orthic-Argustoll): S. Dakota; steppe; clay loess	0—9	6,8[b]	26,4	7,95	1	20,0	5,8	5,9	—	1,7	33,4
	9—20	6,1	34,3	3,97	1	17,4	7,1	5,0	—	1,3	30,8
	20—35	6,9	31,4	2,58	1	18,3	6,8	3,0	0,1	0,7	28,9
	35—48	7,9	25,7	1,70	16	—	—	—	0,1	—	—
	48—65	7,9	26,0	0,93	15	—	—	—	0,2	—	—
	65—88	8,0	31,4	0,56	15	—	—	—	1,4	—	—
	88—105	8,4	40,1	0,62	21	—	—	—	3,4	—	—
	105—150	8,6	34,2	0,52	12	—	—	—	5,2	—	—
8. Low humus (southern) chernozem — Southern chern. (Argustoll); Nebraska; plowland; loess (guide to third excursion)	0—13	6,2	23,6	2,36	—	12,2	3,8	4,7	0,1	1,2	22,0
	13—23	6,8	31,8	2,15	—	15,9	5,3	4,3	0,1	1,2	26,9
	23—30	6.8	38,3	1,65	—	17,6	6,5	3,5	0,2	1,6	29,4
	30—50	7,2	41,8	1,08	—	19,1	7,8	3,6	0,4	2,1	32,4
	50—65	7,2	36,6	0,67	—	18,5	7,8	2,3	0,5	2,4	31,5
	65—80	7,8	29,6	0.45	—	19,8	7,3	0,8	0,6	2,4	30,9
	80—108	8,1	20,7	0,29	2	30,9	7,2	—	0,8	2,5	41,5
	108—132	8,3	22,0	0,22	1	25.0	6,8	—	1,2	2,7	35,5
	132—155	8,2	21,1	0,24	1	18,6	5,6	—	1,4	2,4	28,0
	155—210	8,2	23,2	0,24	1	16,8	5,9	—	1,6	2,3	26,6
	210—255	8.3	21.0	0,24	2	25,3	5,3	—	1,8	2,3	34,7
	255—300	8,3	20,5	0,31	1	17,4	5,5	—	1,9	2,2	27.0
9. Chestnut soil (Orthic Argustoll) Nebraska; short grass steppe; loess (Guy Smith)	0—15	7,6	18,9	2,18	—	13,3	2,1	4,7	—	2,1	22,2
	15—20	7,3	19,4	2,06	—	12,1	2,4	4,3	—	1,9	20,7
	20—28	7,3	26,5	1,12	—	12,9	4,1	3,2	—	2,0	22,2
	28—50	7,6	33,2	0,89	—	17,2	7,2	2,8	0,2	2,8	30,2
	50—58	8,3	28,6	1,27	9	—	—	—	0,2	3,0	—
	50—70	8,5	21,2	0,60	12	—	—	—	0,4	2,7	—
	70—85	8,7	14,4	0,20	8	—	—	—	0,5	2,1	—
	85—113	8,8	16,9	0,09	8	—	—	—	0,6	2,3	—
10. Brown desert-steppe (solodized-solonetzic) soil — Brown soil (Aridisol); Colorado; plowland; silty clay (guide to third excursion)	0—13	7,1[b]	19,7	1,74	0,5	11,0[c]		—	1,0	1,3	13,3
	13—18	7,2	19,7	1,56	0,3	16,3		—	0,7	1,0	18,0
	18—36	7,2	34,2	1,38	0,4	25,8		—	0,9	1,0	27,7
	36—51	7,8	23,2	1,26	13,9	23,1		—	1,2	1,7	26,0
	51—80	8,0	16,7	0,64	13,2	20,2		—	1,8	2,0	24,0
	80—123	8,0	13,1	0,40	9,0	18,1		—	1,7	1,9	21,7
	123—154	7,5	18,1	0,28	5,9	16,8		—	1,6	1,6	20,0
11. Cinnamon-brown soil — Gray Wooded soil (Typaltalf) Colorado; mountain forest of *Pinus ponderosa* with *Agropyrum* sp., bearberry and cacti; on granite weathering products (guide to 3rd excursion)	0—2	6,0[b]	7,3	4,16	—	4,3	2,7	4,0	0,6	0,6	12,2
	2—12	6,5	11,4	1,51	—	3,5	1,9	3,8	0,8	0,6	10,6
	12—22	6,2	24,6	1,24	—	7,9	2,3	3,4	0,6	0,6	14,8
	22—40	6,3	29,7	0,57	—	9,9	5,6	5,7	0,4	1,0	22,6
	40—55	6,5	26,8	0,41	—	8,7	4,4	4,3	0,6	0,8	18,8
	55—80	6,8	21,2	0,33	—	9,1	1,9	2,8	0,6	0,6	15,0
	80—120	7,8	12,8	0,62	3,6	—	—	—	0,6	0,4	—

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[a] Exchange acidity; [b] pH plate; [c] Total of exchangeable Ca + Mg.

Note: Comma represents decimal point.

like, typical, and podzolized brunizems; the brunizem zone can be divided similarly into three meridional subzones. In the easternmost section of these subzones brown forest soils beneath broadleaf forests are widely distributed on dissected slopes. Brunizems with the ground water table near the surface (2 m-3 m), clearly defined gleying in the horizon beneath the humus and enhanced humus content (7%-9%) are found on level undrained areas in all the subzones. In Russian terminology these soils might be called meadow-brunizems; the most moist, which are called humic gley soils in the USA, give way gradually to meadow-bog soils. Differences in relief and in wetting within the brunizem zone lead to an intricate combination of soils which is reflected in the large-scale county soil maps that are normally compiled on the principle of soil series.

Participants on the second excursion observed the following typical soil combinations in the eastern brunizem subzone in Illinois: level surfaces and gentle slopes were occupied by brunizems, among which there were humic-gley soils on slightly drained plains and distinctive gleyed and podzolized soils known as "planosols" in small depressions. Now or in the past slopes leading down to rivers and all dissected areas and areas of coarse-texture are or have been covered by broadleaf forests and are brown forest soils with distinct signs of podzolization on the gentler slopes.

Those who went on the third excursion to Iowa saw three different soil combinations. The eastern slope of the wide poorly drained Mississippi-Missouri watershed has a combination of typical brunizems and brown forest soils on the steeper slopes; in its central sector meadow-brunizems are commonest on level areas and typical brunizems on gently rolling slopes; "meadow" chernozem-like brunizems (the Marshall series) are commonest on the western slope to the Missouri but there are spots of meadow-brunizem soils.

Soils of the brunizem group are well supplied with heat, do not suffer from summer droughts, and are widely used for agriculture. They have clearly been greatly affected by the crop, which has brought about some alteration in the hydrological regime and in the conditions of humus accumulation. The main agricultural crop on brunizems is corn. Grass cultivation is also common.

Although the brunizems of the US are similar in some features to the soils of the distinctive prairies of the Soviet Far East ("climatic meadow formation" and lack of carbonates) they differ from them in temperature conditions and in the seasonal course of wetting.

As one moves to the west the zone of chernozem-like prairie soils (brunizems) is replaced by a zone of chernozem-chestnut brown steppe soils; total annual precipitation decreases and annual evaporation rises. The general climatic features of the center of the steppe zone in the United States are shown by data from the North Platte (Nebraska) Meteorological Station. The steppes of the US differ from those of the USSR (Rostov-on-Don) in that moisture is very uniform throughout the year; the steppe soils of the US are also less wetted than those of the USSR in the winter and spring and considerably more wetted in the summer (Fig. 2d). A connection can here be seen with the deeper situation of carbonate horizons in the steppe soils of the US, their lower total carbonate content and the considerable extent to which easily-soluble salts have been leached (Table 2).

Almost all the chernozems and chestnut-brown soils of the United States and Canada are now plowed. In the past they were covered by grass vegetation of steppe type consisting largely of beard grasses (Andropogon gerardi and A. scoparius), feather mass (Stipa spartea) with some grama grass (Bouteloua curtipendula and B. gracilis) in the east, and buffalo grass (Bulbilis dactyloides) in the west. In addition to the grasses there are various grasses including xerophitic species (Artemisia frigida, etc.) in the west.[6]

The meridional steppe zone, which is widest at latitude 45° (approximately 1200 km) is considerably narrower (approximately 600 km-700 km) at latitude 40° where the excursion passed through it. In this depth four meridional subzones can probably be distinguished: higher humus chernozems ("ordinary North American") similar in their position in the zonal system to our ordinary chernozems; lower humus chernozems ("southern North American") similar (by the same attributes) to our southern chernozems and dark and light chestnut soils, the boundary between which is not very distinct.

The steppe soils of these North American subzones have properties that differ considerably from those of their European analogues are similar in some respects to the chernozems and chestnut soils of Eastern Asia. Typical features include: 1) an illuvial-carbonate horizon at a low level, 2) comparatively uniform thickness of the humus horizon (50 cm for chernozems and 30 cm-40 cm for chestnut soils), 3) relatively low humus content, 4) lower total content of humus in the soil profiles (as compared to European soils), and 5) leaching of easily-soluble salts wherever the soils occur under zonal conditions.

Profile 7 in Table 2 (quoted from Guy Smith) has a high humus content in the uppermost layer. The profile was selected beneath virgin steppe vegetation on a carbonate fine-textured parent material (there are signs of the removal of carbonates); the soils of profiles 8 and 9 effervesce at a low level, contain little humus, and have much more calcium than magnesium in the adsorbed cations even at a depth of 255 cm-300 cm. The texture of the soil-forming parent materials is not absolutely uniform (there is layering) and there are therefore variations in total adsorption capacity.

There are undoubtedly specific provincial and facies features to the chernozems and chestnut soils of the United States and Canada, but in the meridional extension of the soil zones these are associated more with thermal differences than, as in the USSR, with the moisture regime.

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[6] The term "prairie" is sometimes applied to this type of vegetation in American literature, in our opinion incorrectly.

High mycelial carbonate content is nowhere apparent. Signs of slight solonetzization are apparently more common in the eastern subzone of higher humus chernozems mainly owing to inadequate drainage and the meadow regime. Here planosols (distinctive surface gleyed and podzolized soils) occur in "steppe saucers". "Steppe solonetzization that is so typical of the chernozems and chestnut soils of Kazakhstan is apparently very uncommon in the US.

The chernozems and chestnut soils of the United States are widely used for agriculture, mainly for grain crops; because of the more favorable summer moisture, they plow light chestnut soils that cannot be used in the USSR.

Approximately to the west of 104th parallel the steppe zone of the boreal belt is replaced by a desert zone of brown semi-desert soils that extend to the foothills of the Rocky Mountains. Precipitation here decreases to 170 mm-200 mm. The soils need irrigation, but since the general distribution of moisture by seasons is similar to the steppe zone, crops can be obtained without irrigation.

The vegetation consists largely of low xerophytic gramineous plants (Bouteloua gracilis, Bulbilis dactyloides) and also contains species of wormwood, yucca, opuntia and certain other xerophilous plants. This type of vegetation, which is called short grass, remains on many unplowed areas in the eastern part of Colorado and is used for pastures.

We examined the profiles of brown semi-desert soils on plowland at a farm in Akron and beneath the virgin vegetation on the Banning-Lewis ranch. The humus horizon (brownish-gray) was 17 cm thick in the profile at Akron, its lower part was lighter in color and beneath it the soil was compacted owing to the solonetzization of the soils. A sharply defined illuvial-carbonate horizon with a high $CaCO_3$ content began at a depth of 36 cm (Table 2, Profile 10). The solonetzic differentiation of the profile is clearly apparent from the clay distribution and the total adsorbed cations, although the content of adsorbed sodium is slight. In the profile on the Banning-Lewis ranch the humus horizon was slightly more gray in color, there was sod formation from the surface and only slightly apparent signs of solonetzization. Some of those present thought that this soil was similar to a light chestnut soil.

Irrigation farming is widely practiced at the foot of the Rockies around Fort Collins and Denver on Brown semi-desert soils. The water for this purpose is piped from the basin of the Colorado river from the western slope of the Rockies. The Rocky Mountains rise steeply above the high plains of Colorado. At their foot there is a narrow foothill transitional strip consisting of chestnut soils and possibly low-humus chernozems (which we were not able to study more closely). Beyond this there is a wide vertical belt of distinctive brown forest soils.

The brown forest soils of the Rocky Mountains differ from those of the Appalachians and other districts in the United States in that they have developed mainly beneath coniferous forests under generally arid conditions and therefore have specific features.

The coniferous forests of the Rocky mountains are protected in the extensive national parks containing a wealth of species. Pines (Pinus ponderosa, P. contorta, and P. edulis) predominate, but there are also plenty of spruces (Pica pungens and P. engelmani), firs (Abies concolor and A. lisicarpa), Douglas fir (Pseudotsunga menziessi), and juniper. The commonest deciduous trees are aspen (Populus tremuloides), stunted oak (Quercus gambiclü), and ash-leaved maple (Acer negundo). Ground cover in these forests consists mainly of grasses and is xerophilous in places. At a forest station to the west of Colorado Springs we found Euagropyrum sp., wormwood, small cacti and, among the cacti, barberry (Arctostaphylos uva ursi). The soils of the forest station, which are formed on granites, are classified in the guide as gray wooded soils. Their profile contains a number of features that are common to cinnamon-brown soils: the presence of a carbonate horizon, gradual decrease in humus, cinnamon-brown humus horizon, and a reddish tinge to the granite eluvium possibly associated with a preceding stage of soil formation (Table 2, profile 11).

The climate in the vicinity of the station is temperate (July temperature approximately 16°C, January temperature -5°C). The soil profile shows clear accumulation of clay in the horizon and it is therefore more correct to treat it as a brown or gray forest soil altered by arid conditions. In Western Europe similar soils in the Northern Balkans have been called cinnamon-brown to brown.

The Rockies also contain quite extensive areas of more humid brown forest soils with signs of podzolization and higher altitudes further to the north. These soils were seen at a forest experiment station to the south of Lake Granby. They contain approximately 3%-4% humus, and have a pH of 4.7. Adsorption capacity is approximately 30 meq of which 20 meq is hydrogen. Above the treeline the brown forest soils are replaced by mountain-meadow skeletal soils in which mountain-meadow peaty soils with a thin peat horizon are in evidence.

Participants on the excursions saw the soils of the subtropical belt in the extreme east (red earths and yellow earths) and west (the Colorado plateau and southern California). The zone of subtropical yellow earths and red earths lie to the south of the brown forest soil zone, and extend from the Atlantic seaboard in the east to the Ozark Plateau in the west (1500 km-1600 km) and from the mouth of the Missouri in the north to the Gulf of Mexico in the south (approximately 1000 km).

The main soil-forming parent materials on which contemporary processes of soil formation are taking place are ancient "red color" crusts that are the weathering products of Paleozoic sedimentary and crystalline rocks, friable marine sand and clay loam deposits, loesses, and the recent alluvial deposits of the Mississippi and its tributaries.

The natural timber of the zone consists of mixed but mainly broadleaf virgin forests containing various species of oak, hickory, pine, and many other types.

The soils formed beneath these forests are mainly yellow earths and red earths (red-yellow podzolic soils) in which the process of podzolization is expressed to varying degrees. Clearly distinct beneath the thin (1 cm-2 cm) dark brown friable accumulative horizon there is a podzolized horizon depleted of clay and exchangeable bases that is brownish yellow or rose and considerably lighter. At a depth of 15 cm-20 cm. this gives way to a red or yellow-orange compact illuvial metamorphic horizon in which clay is accumulated and which has an indistinct prismatic-lumpy structure. At a depth of 100 cm-150 cm this horizon gives way gradually to the highly weathered red or red-yellow parent material that is depleated of bases, normally less compact and has a high R_2O_3 content (Table 1, profile 5).

The warm humid climate in which red-yellow podzolic soils develop leads to rapid mineralization of organic matter, removal of organo-mineral compounds from the profile and low humus content in the soils (Table 1, profile 5). Reaction is acid throughout the profile and there is considerable clay accumulation in the center of the profile. The existence of podzolization processes is indicated by a certain depletion of clay and redistribution of the exchangeable cations. Nevertheless, the comparatively narrow $SiO_2:R_2O_3$ ratios in the clay fraction of the soils and the existence of an admittedly slight narrowing of these ratios (2.5) in the podzolized horizon by comparison with the parent material (2.6) (G. Smith "Soil Classification", 1960) suggest, when taken in conjunction with the mineralogical composition of the colloidal fraction, that the contemporary processes of soil formation are towards the formation of red-yellow podzolic soils. The guide book for the second excursion states that the clay minerals of these soils include: kaolinite (>40%), vermiculite (10%-40%) and quartz (<10%) in the A_2 horizon; kaolinite (>40%), vermiculite (10%-20%), and gibbsite (<10%) in the B_2 horizon; kaolinite (>40%), vermiculite (10%), and gibbsite (10%) in the B_3 horizon.

The considerable east-west extent of the zone ensures some bioclimatic diversity. The ancient mountain formation of the Appalachians divides the zone naturally into two bioclimatic meridional subzones. The eastern (Atlantic) subzone (Fig. 2b, Ashville Station) has a humid and slightly cooler climate with little or no drought in the summer. The western meridional subzone extending towards the Mississippi and the Ozark Plateau is warmer and has a comparatively pronounced dry summer (Memphis).

The differences in heat and moisture balance between west and east and the nonuniformity and diversity of the parent materials have given rise to an assortment of landscapes and alterations in soil and vegetation in various parts of the humid subtropical zone of the United States.

The Atlantic subzone lying to the east of the Blue Hills (Appalachian Mountains) consists largely of coniferous-deciduous forests (mainly pine and oak) with red-yellow podzolic soils formed on the weathering products of unstratified crystalline and sedimentary metamorphic rocks and ancient "red colored" crusts (Table 1, profile 5). These soils are highly base unsaturated, and have a low content of bases and humus and high exchange acidity.

The commonest tree type in these natural forests is the white oak (especially Quercus alba). The pine forests are confined to dry localities and thin, poorly developed soils. Colonization and the cutting of the forests have led to a great expansion of secondary pine forests consisting largely of Pinus taeda, P. echinata, and P. virginiana and most of the soils have become yellow earth and eroded earth soils.

The contemporary forests of the Atlantic subzone also include various species of oak, hickory (Carya pecan), Persian walnut (Juglands regia), and sweet gum (Liquidambar).

In addition to the highly unsaturated red earths and yellow earths (red-yellow podzolic soils) formed on the weathering products of acid crystalline rocks, the Atlantic area also contains reddish-brown (lateritic) soils and surface gleyed podzolized yellow earths (red-yellow podzolic soils) with a surface-gleyed clay horizon known in American literature as fragipan.

Red-brown soils are confined to dark ferromagnesian parent material such as diorites and gabbro and, in part, to carbonate parent materials, the weathering products of which are normally rich in sesquioxides and bases and have a high pH. These soils have a dark reddish-brown humus accumulative horizon, no podzolized horizon and considerable clay accumulation throughout the profile.

Yellow earth podzolized surface-gleyed soils with "fragipan" are formed on the weathering products of argillites and parent materials with a high clay content cemented with silica if drainage is considerably worsened. Such soils are normally very acid and highly base unsaturated and contain a great deal of exchangeable aluminum in the B and C horizons.

The Atlantic coastal plain differs considerably from the remainder of the subzone in the nature of the relief and soil-forming parent materials and in the dominant vegetation and soils. Humus and humus-iron podzols with a humus-iron alluvial horizon, that is often cemented. form here on the inadequately drained coastal plains in which the ground water lies close to the surface beneath sparse, stunted forests of Pinus taeda and in well drained areas beneath forests of Pinus palustre, Quercus laevis, and Q. marilandica. Like half bog peaty-gley and moor peat soils and marsh soils, these soils occupy a considerable area in the Atlantic coastal sector of the subzone.

The subtropical subzone to the west of the Appalachians has a drier climate than the eastern subzone in view of the drier summer (Fig. 2 b, Memphis Station), and this is reflected in the processes and properties of the red earths and yellow earths that predominate in this part of the zone.

The red earths and yellow earths (red-yellow podzolic soils) that form on the ancient "red colored" weathering products of sedimentary and metamorphic rocks, beneath oak and hickory forests containing a fair amount of plane, elm, ash, sugar maple, and red gum tree, are less base unsaturated and acid than are the similar soils in the eastern subzone, contain slightly more humus and show a greater tendency for biological accumulation of bases in the upper part of the profile (Table 1, profile 6).

The nature of the parent materials and the relief have a considerable effect on the processes of soil formation here. Brown podzolized soils that are clearly similar to yellow-brown forest podzolized soils form on young carbonate loesses depleted of sesquioxides when drainage is good.

The wide plain of the Mississippi valley, consisting of young sand and clay loam alluvium, is noted for its abundance of fertile meadow-alluvial sandy and sandy loam soils. On the less drained areas of terraces and on the bottomland dark massive highly clayed and gleyed soils, reminiscent of the smolintsay of Yugoslavia, form on clay and clay loam alluvial deposits. These soils are slightly acid or neutral, base saturated, and contain between 2% and 3% of humus. The high content of the colloidal fraction is a distinctive feature (the content of clay in these soils reaches 70%). American soil scientists consider that soils of this type are intermediate between grumosol soils and alluvial soils. They are mainly distributed in the subtropical belt, although clay and clay loam alluvial deposits occur regularly in other belts.

Red earths and yellow earths podzolic soils form on the weathering products of massive crystalline and sedimentary metamorphic rocks and on the redeposited weathering products of "red colored" crusts beneath natural forest vegetation where the relief is gentle and slightly dissected. The upper podzolized horizon is normally absent and eroded red and yellow earths predominate where the relief is greatly dissected.

The summer is drier throughout the North American red and yellow earths zone than in the humid subtropics of the Soviet Union except for the narrow strip of the humid Atlantic seaboard and the dryness increases towards the west. This probably accounts for their greater podzolization and lesser gleying. Cotton, rice, citrus fruits, and tobacco are of great importance to agriculture in the humid subtropics of the United States. Cotton is irrigated in the west.

To the west of the Mississippi the yellow earth podzolic soils are gradually replaced by reddish-black soils of the prairie (Reddish-prairie soils) that form a narrow meridional zone. Further to the west in Oklahoma and Texas there are meridional zones of cinnamon-brown, gray-cinnamon-brown, and gray soils (reddish-chestnut and reddish-brown in the American terminology). The Congress materials do not contain any new information on the soils of these zones.

Participants on the third excursion only encountered the soils of the arid subtropics on the Colorado Plateau (New Mexico and Arizona) and in California. Guy Smith also gives information on these States.

The Colorado Plateau, which is protected in the north and west by the high ranges of the Rocky Mountains, continued in the south-west by the Sangre de Cristo Mountains, is at an absolute altitude of between 1700 m and 2000 m. It includes small monadnocks normally of crystalline rocks. Lava sheets on sedimentary rocks are of common occurrence.

The Colorado Plateau has distinctive vegetation consisting largely of semi-desert plants in which a discontinuous cover of black grama (Bouteloua eripoda) and other gramineous plants is interspersed by creosote bush, wormwood and low junipers. Joshua and yucca trees and various types of cacti are also found in places. The cacti tree of Arizona (Cereus and Carnegia) were particularly inpressive. There were denser thickets of Juniperus monosperma, xerophilous pine (Pinus edulis). and oak (Quercus gambieli) on the slopes of uplands and mountains and high forests of pine and fir at great altitudes.

Comparison of data from the Santa Fe and Tashkent Meteorological Stations gives a clear picture of the climatic features of the plateau. Although mean annual indixes are comparable (Fig. 2e), moisture is extremely uniform throughout the seasons at Santa Fe whereas there is a distinctive dry summer period at Tashkent. The soils of the Colorado Plateau, which have a typical reddish tinge, are called reddish-chestnut, reddish-brown, and brown soils in the guide book. Red desert soils are also distinguished in the Painted Desert and other desert areas.

Some analytical data for these soils are given in Table 3. Beneath the grasses and low junipers the soil formed on the weathering products of volcanic rocks (Fig. 12), effervesces at a depth of 25 cm, contains approximately 2% of humus and contains accumulated clay and is massive in the lower part of the profile. The significant content of exchangeable hydrogen, apparently determined with alkaline salts, is a distinctive feature.

Profile 13 examined by participants on the third excursion was somewhat more moist. The humus content was lower (1.5%) and accumulation of clay began at the surface; acid effervescence began at approximately 30 cm. Features of slight meadowing and the protrusion of stone fragments at the surface were observed in the profile. The soil was defined as a subtropical grumosol although there were

Table 3

Analytical description of the soils of the arid subtropics of the US

Profile No., soil, position, vegetation, and parent material	Depth, cm	pH water (1:1)	Clay <0,002, мм diam.	Humus %	CaCO$_3$, eq. %	Adsorbed cations, meq/100 g					
						Ca	Mg	H[a]	Na	K	Total
12. Grey — cinnamon brown (compact soil) — Reddish Brown soil (Orthic Mazustert); Arizona; Low herbaceous Juniper, opuntia, and yucca; weathering products of basic volcanic rocks (Guy Smith)	0—3	6,0	31,3	2,13	—	16,4	8,0	5,6	0,09	1,40	31,5
	3—10	5,2	35,2	2,09	—	18,0	8,5	8,6	0,16	0,98	36,3
	10—25	6,3	42,8	1,54	—	26,4	9,9	4,6	0,28	0,85	42,0
	25—43	7,5	42,8	0,96	2	32,1	8,2	—	0,74	0,68	41,7
	43—73	7,7	43,0	0,89	2	—	—	—	—	—	—
	73—85	7,7	43,4	1,06	2	—	—	—	—	—	—
13. Grumosol (Grumustert); Arizona; Low herbaceous juniper; on olivine-basalt weathering product (guide to third excursion)	0—2,5	7,1	43,8	1,55	—	30,0	8,8	2,2	0,10	1,08	42,2
	2,5—12,5	6,8	43,9	1,26	—	33,6	7,6	2,8	0,27	0,94	45,2
	12,5—25	7,4	45,0	1,07	—	36,9	8,1	1,2	0,45	0,90	47,6
	25—42,5	7,7	45,0	0,89	1	—	—	—	—	—	—
	42,5—70	7,8	45,5	0,76	2	—	—	—	—	—	—
	70—87,5	7,8	46,3	0,79	2	—	—	—	—	—	—
	87,5—112	7,9	44,1	0,72	3	—	—	—	—	—	—
	>112,5	7,8	45,1	0,72	2	—	—	—	—	—	—
14. Sierozem (Haplargid); Arizona; shrub semi-desert; aluvium (materials of third excursion)	0—10	7,2[b]	10,6	0,27	—	7,7	8,0	—	0,1	0,9	16,7
	10—25	7,5	13,8	0,21	—	9,6	8,7	—	0,3	0,6	18,9
	25—48	7,6	21,6	0,24	—	13,9	10,8	—	0,5	0,4	25,6
	48—68	8,1	27,9	0,27	2	29,1	13,5	—	0,6	0,4	—
	68—93	8,1	21,5	0,27	10	27,9	9,6	—	0,7	0,3	—
	93—135	8,6	16,6	0,07	22	21,6	8,0	—	0,8	0,2	—
	135—190	8,8	14,9	0,03	15	24,5	11,4	—	1,2	0,2	—
	190—245	9,0	5,7	0,02	6	19,5	9,1	—	1,2	0,2	—
15. Grey-cinnamon brown noncarbonate — noncalcic Brown soil (typustalf); California; Plowland; ancient aluminum (materials of third excursion)	0—23	6,3[c]	4,3	0,50	None	2,5	0,8	1,7	<0,1	0,4	5,5
	23—33	6,7	6,8	0,41	"	3,5	0,9	1,2	0,1	0,3	6,0
	33—43	7,1	9,0	0,36	"	4,7	1,1	1,1	0,1	0,3	7,3
	43—60	7,7	14,0	0,29	"	6,1	1.9	1,2	0,1	0,2	9,5
	60—78	7,6	15,4	0,26	"	6,7	2,5	1,4	0,1	0,2	10,6
	78—113	7,9	18,9	0,21	"	7,0	2,9	1,3	0,2	0,1	12,1
	113—128	7,8	15,1	0,14	"	6,6	2,6	2,2	0,2	0,1	11,7
	128—145	7,5	11,3	0,10	"	5,4	2,2	0,5	0,2	0,1	8,4
	145—168	7,5	6,1	0,09	"	4,3	1,6	0,5	0,1	0,1	6,6
	168—218	7,5	6,0	0,07	"	5,0	1,6	—	0,2	<0,1	6,9
	218—240	8,7	7,0	0,07	<1	7,6	2,5	—	0,2	0,1	10,5
16. Noncarbonate sierozem — Red Desert soil (Haplargid); California; shrub semi-desert; Aluvial deposits (materials of third excursion) weath. pr. (gd. 34 dex.)	0—13	7,8[c]	3,1	0,36	—	3,5	0,5	0	0,1	0,2	4,6
	13—20	7,8	11,4	0,21	—	5,3	1,7	0.6	0,1	0,3	8,0
	20—45	7,6	24,2	0,24	—	13,1	3,5	1,4	0,1	0,3	18,4
	45—80	7,4	16,4	0,27	—	9,7	2,1	0,7	0,2	0,2	12,9
	80—100	8,9	16,4	0,24	<1	13,1	2,1	0,7	0,2	0,2	16,3
	100—113	8,9	12,9	0,17	—	11,3	1,8	0,3	0,1	0,2	13,7
	113—150	8,9	8,1	0,12	—	6,8	1,1	0,0	0,1	0,1	8,1

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[a] Exchange acidity; [b] pH paste; [c] pH 0. 1.

Note: Comma represents decimal point.

distinct features of cinnamonic soil formation.

Soils with an even lower humus content, low adsorption capacity, and effervescence in the lower part of the first 50 cm, partly associated with coarser texture, form under more arid conditions on alluvial deposits. Carbonate content is high; as in the previous profiles of soils of this type adsorbed magnesium plays an important part (Table 3, profile 14) — there is little adsorbed sodium.

What is the position of these soils in the world classification system? Should they be classified as cinnamon-brown, gray-cinnamon-brown and sierozem despite their special morphological features and the apparently distinctive vegetation? In our opinion they should be so classified in view of their biological and agricultural features, primarily in relation to the conditions under which organic matter is accumulated and decomposed, to the fact that they are mainly formed on largely gramineous semidesert cenoses and to the extensive development of clay accumulation, which is a particularly distinct feature of soil formation on basic parent material. Our opinion is also guided by the agricultural use to which the soils are put, the crops grown, the need for irrigation and certain other agricultural features. These soils will be a special new facies subgroup of cinnamon-brown, gray-cinnamon-brown, and sierozem soils occupying extensive areas both in the United States and further to the south on the Mexican Plateau. This calls for a certain extension of the concepts of the sierozem and gray-cinnamonic soil groups that are largely based on materials from Central Asia and the Levant that are very narrow from the geographic viewpoint.

The meridional course of the Colorado River is an important soil and bioclimatic boundary between the distinctive Central American subtropical region here described and the Western American subtropical region that lies in California and extends southwards into Mexico.

The specific climatic features of the Western American subtropical region are to be found in the annual precipitation in which it is greatest in the color seasons and absent in the hot summer months. This typical Mediterranean type of moisture is clearly apparent on the graph for the Fresno Station in California (Fig. 2d). It is completely analagous to curves for the Kyzyl-Arvat Station (Turkmenia) and differs markedly from the Santa Fe Station in New Mexico (Fig. 2e).

Since the very similar climatic conditions in the arid districts of California and in the Eastern Mediterranean are reinforced by a certain similarity in vegetation (ephemers and ephemeridae are a major factor in both cases) it would appear that there ought to be similar soils. References in the literature and our own observations give a completely different picture. The soils of California, which we have ascribed to the gray-cinnamonic and sierozem groups on the basis of a combination of other attributes, do not contain free calcium carbonate or effervesce at a considerable depth (Table 3, profiles 15 and 16). They contain little humus and are morphologically clearly defined horizons of clay accumulation with a higher content of the clay fraction forming in the central sector of their profile. The adsorption complex is saturated with bases (calcium predominates and there is very little sodium). In the American classification these soils are ascribed to the noncalcic brown desert soil and red desert soil groups. In places they have highly compacted middle horizons (hardpan), such horizons may also develop following irrigation. If the Californian soils are compared with the soils of other Mediterranean districts, it can be seen that these features are not explained by the recent climatic features of the region. The contemporary seasonal course of moisture cannot lead to the removal of calcium carbonate and one is forced to assume that the low carbonate content of these Californian soils is partly due either to initial non-carbonate composition of the soil-forming parent materials or to an earlier and more humid climatic stage, which may here have been during and after the Ice Age (pluvial epochs).

Due to its warm climate, the absence of cold winters, favorable conditions for irrigation and the limited extent of saline soils and secondary salinized soils, California is one of the richest agricultural districts of the United States and produces cotton, citrus fruits, grapes, dates, and a wide range of other valuable crops.

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METHODS

USE OF ELECTRODIALYSIS TO EXTRACT EXCHANGEABLE BASES (Ca and Mg) FROM SOIL[1]

L. P. ORLOVA, V. V. Dokuchayev Soil Institute

Electrodialysis is now being widely used in science and technology (3, 7, 10). In soil research it is used to study the colloidal fraction (1, 5, 6), to determine the amounts of potassium and phosphorus in the soil and to extract exchangeable bases (Ca and Mg) (2, 8).

K. K. Gedroyts was of the opinion that electrodialysis might find particular application in the determination of exchangeable bases in the soil; because when exchangeable cations are extracted by salt solutions, the solutions have the effect of flocculating the colloidal part of the soil and "absolutely complete extraction of exchangeable bases is not possible with salt solutions" (4).

Extraction by electrodialysis is very slow when the electrolyte requires distilled water. Various investigators have cited extraction times between 5 and 160 hr (6, 8). The method has not, therefore, been widely used to extract exchangeable bases from the soil. Extraction of magnesium by electrodialysis of soil in water is particularly slow. Grigorov (6) cited Mattson's explanation that magnesium is combined more stably than other cations with the aluminosilicate component of the soil. Gorbunov (5) considers that there are two fractions of exchangeable magnesium in the soil; one of which (the most dissociated) is combined with organic matter and the other of which is combined with the mineral part of the soil. Grigorov and others (6) are of the opinion that as the soil is depleted of bases in the course of electrodialysis and as the cations migrate to the cathode, deposition of magnesium hydroxide $[Mg(OH)_2]$ on the membrane is facilitated by the development of a strongly alkaline reaction at the cathode. This impedes the movement of the magnesium into the cathode chamber.

Purvis and Hanna [9] have developed a method for the rapid electrodialysis of soils in an 0.5 N boric acid solution that eliminates the high alkalization in the cathode membrane zone and promotes rapid extraction of the exchangeable bases.

Boric acid (H_3BO_3 – orthoboric) is an easily dissociated acid, its dissociation constants being 6.4×10^{-10} at 25°C when the pH of the 0.05 N solution is 5.4. Purvis and Hanna achieved total extraction of exchangeable bases from the soil in 20 min by electrodialysis in a boric acid solution. They used special miniature equipment in which the distance between the electrodes in the small chambers was 3/8" (approximately 1 cm); a 5 g sample of soil placed in the middle chamber was not disturbed during the electrodialysis. They used Whatman Number 5 filter paper as a membrane. The current employed was rarely in excess of 0.2 amp at 110 V. The Ca, Na, and K were determined by flame photometry and magnesium by colorimetry.

I have attempted to establish whether or not electrodialysis can be used to extract exchangeable bases from the soil, and if so what could be the optimum extraction conditions. In my research I took into consideration the method proposed by Purvis and Hanna (9).

The electrodialysis was conducted in a three-chamber Pauli electro-dialyzer with a plexiglass chamber. The central chamber (2 cm wide, volume 80 cc) was separated from the cathode and anode chambers by two membranes, beyond which were the platinum grids acting as electrodes connected to a dc source. The side chambers were 6 cm-7 cm wide and had a volume of 250 cc. When assembled the apparatus was mounted on metal frames by screw clips. Parchment was used as a membrane since filter paper and the various filters at our disposal did not give satisfactory results. Before use the parchment was cleaned by prolonged boiling (2 hr-3 hr) in distilled water followed by electrodialysis in distilled water for 5 hr. A 5 g sample of soil and 70 cc of 0.05 N H_3BO_3 solution was placed in the central chamber. The ratio between the solid and liquid phases in the central chamber was 1:14. Throughout the electrodialysis the soil was stirred with an electrically-operated stirring rod. Mixing was improved by dividing the end of a rubber tube placed over the glass stirring rod vertically into four pieces which functioned as paddles on rotation of the rod.

After the apparatus had been set up, the dc current was not turned on until after the soil had been well-mixed with the electrolyte. The

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[1] Work was done under the supervision of V.A. Chernov.

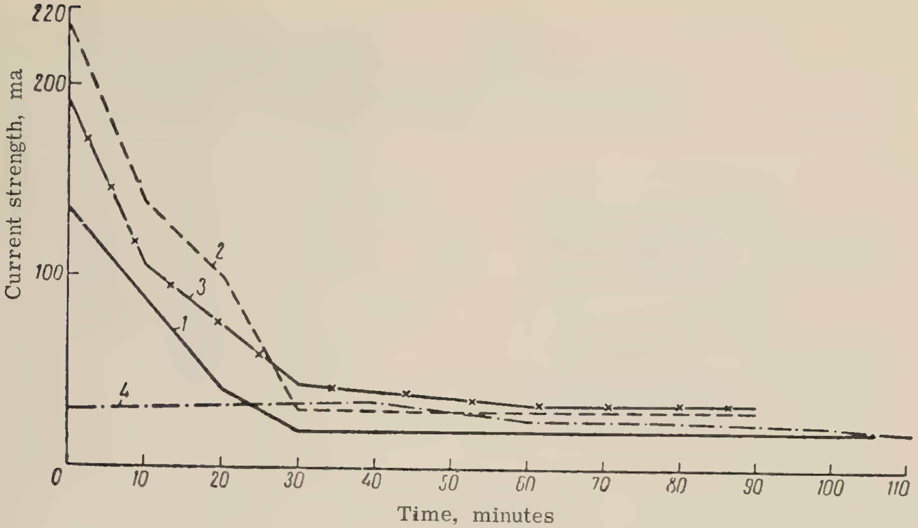

Fig. 1. - Change in current strength during electrodialysis: Profiles: 1-31 A_2; 2 - $9A_2/B_1$; 3 - 259 B_1; 4 - boric acid.

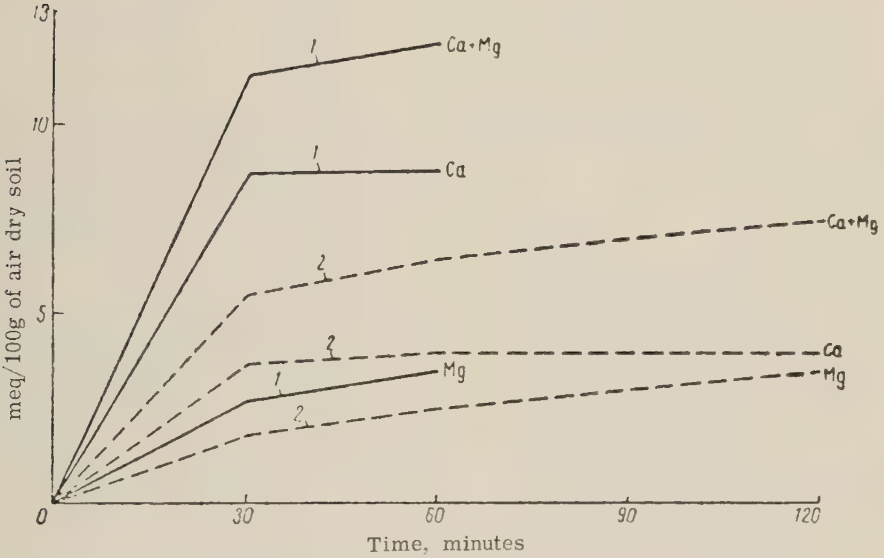

Fig. 2. - Course of extraction of exchangeable bases on electrodialysis of soil in boric acid solution. Profiles: 1-31 A_1; 2 - 262 B_2.

rectifier used as a dc source could be regulated to provide a current of between 300 V and 600 V at the terminals. The current used in the experiments varied between 100 ma and 200 ma. The temperature of the catholytes when decanted was 40°C-50°C.

Figure 1 shows the change in current strength during the course of electrodialysis. It revealed that current strength declined sharply and became stable within 30 min of electrodialysis, at which time it was approximately the same as the current strength in electrodialysis of pure boric acid. Figure 2 shows that the bulk of the exchangeable bases was extracted in this half-hour period. There was a slight increase in the amount of extracted bases, mainly as the result of extraction of magnesium, if the electrodialysis was further prolonged. After 1.5 hr of electrodialysis the contents of the central chamber were filtered; silicic acid was detected in the filtrate, whereas no traces of silicic acid were detected in extracts of the same soil when the soil was agitated with 0.05 N boric acid for 1 hr and 2 hr. It can therefore be assumed that prolonged electro-

Table 1

Replicated determinations of exchangeable bases extracted from the soil by electrodialysis, meq per 100 g of air dry soil. Horizon B_1

Depth, cm	Soil	Ca + Mg	Ca	Mg
45—55	Light gray, forest, strongly podzolized	11,7	8,7	3,0
		11,7	8,4	3,3
		11,7	9,0	2,7
40—45	Leached chernozem	12,5	9,5	3,0
		14,0	11,0	3,0
		13,5	10,5	3,0

Note: Comma represents decimal point.

Table 2

Content of exchangeable bases, meq per 100 g of air dry soil

			Soils	pH 1,0 n KCl	Extraction					
					By ammonium acetate			By electrodialysis		
					Ca+ +Mg	Ca	Mg	Ca+ +Mg	Ca	Mg
31	A_1	2—11	Light gray strongly podzolized clay loam forest soil	5,1	10,7	7,7	3,0	11,4	8,7	2,7
	A_2	15—25		3,6	4,4	3,4	1,0	4,5	3,0	1,5
	A_2/B_1	28—36		3,8	7,3	5,6	1,7	7,0	5,5	1,5
	B_1	45—55		3,7	12,0	8,8	3,2	12,5	9,5	3,0
	B_2	75—85		3,6	13,4	9,8	3,6	13,4	9,2	4,2
	B_4	150—155		3,7	12,1	8,7	3,4	11,2	8,0	3,2
15	A_p	0—10	Sod-medium podzolic cultivated soil on clay loam mantle	4,5	4,8	3,6	1,2	6,0	5,0	1,0
	A_p	10—20		4,2	6,4	4,8	1,6	6,0	4,8	1,2
	A_2/B_1	30—40		4,0	9,2	6,4	2,8	8,0	5,8	2,2
	B_1	50—60		3,8	10,0	7,6	2,4	10,0	6,5	3,5
	BC	80—90		3,9	8,8	6,4	2,4	8,8	6,0	2,8
	C	103—113		4,0	12,8	9,2	3,6	12,5	8,8	3,7
262	A_0A_{sod}	0—5	Sod-nonpodzolic stony soil	5,6	21,9	15,1	6,8	24,7	18,5	6,2
	A_1/B_1	9—19		5,3	11,7	8,0	3,7	11,5	7,8	3,7
	B_1	25—35		4,9	12,1	8,0	4,1	11,7	8,0	3,7
	B_2	50—60		4,5	4,9	3,8	1,1	5,4	3,7	1,7
	C_1	90—100		5,4	5,6	4,5	1,1	5,3	4,2	1,1
	C_1	140—150		5,4	6,4	4,9	1,5	7,0	4,8	2,2
259	A_{sod}	0—8	Leached medium-thickness chernozem	5,9	17,6	14,4	3,2	17,7	15,0	2,7
	A_1	20—25		5,7	7,5	5,7	1,8	6,7	5,0	1,7
	B_1	40—45		5,7	15,1	11,3	3,8	14,0	11,0	3,0
	B_3	62—67		5,6	17,0	14,0	3,0	17,4	13,7	3,7
	C_1	100—105		7,2	Carbonate					
9	A_1	2—7	Brown mountain-forest deeply leached clay loam on sandy Middle Jurassic parent materials	5,2	13,6	9,1	4,5	13,5	9,5	4,0
	A_2/B_1	10—20		3,6	5,8	3,7	2,1	6,2	3,5	2,7
	B_2	30—40		3,9	5,6	3,4	2,2	6,0	3,8	2,2

Note: Comma represents decimal point.

dialysis of soil in 0.05 N boric acid leads to decomposition of the crystal lattice of the minerals as the soil is depleted of exchangeable bases and becomes saturated with hydrogen, and additional amounts of magnesium and, in part, calcium ions pass into the catholyte.

It was established by studies under the experimental conditions described previously that 30 min is the extraction time required when extracting exchangeable bases from soil by electrodialysis. On conclusion of the electrodialysis the contents of the cathode chamber were decanted into a 250 cc volumetric flask. The inner walls of the chamber were carefully washed with boric acid and the wash water was added to the catholyte in the volumetric flask. The volumetric flask was made up to the mark with boric acid solution, and aliquot portions (100 cc each) were taken from this volume to determine calcium and magnesium by trilon B. When the effect of boric acid on titration of Ca and Mg with trilon B was tested in a series of standard solutions of $CaCl_2$ and $MgSO_4$ it was found not to prevent end determination of these cations. On titration of the catholytes, with murexide and chromogen black as indicators, the color change was distinct, and the end of the titration was precisely established.

Table 1 gives information obtained from replicate determinations of exchangeable bases in soils extracted by electrodialysis. The determinations were made with various noncarbonate soils. The exchangeable bases were extracted from the soil by electrodialysis in boric acid and in a solution of ammonium acetate; in both cases the end determination was made by titration with trilon B. These two methods gave very similar results (Table 2).

In view of its rapidity, extraction by electrodialysis in 0.05 N boric acid and the determination of calcium and magnesium in the catholytes by titration with trilon B can be used for mass determination of exchangeable bases in soil.

Conclusions

Exchangeable bases can be extracted in 30 min by electrodialysis of soil in a solution of boric acid given the following experimental conditions: current 0.1-0.2 amp, voltage 300-500 V, temperature of soil suspension 40°C-50°C. The determination of Ca and Mg is made with trilon B. Results obtained by electrodialysis are in agreement with extraction using ammonium acetate. This method is more rapid.

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REVIEWS

SOIL AND AGROCHEMICAL TERMINOLOGY IN THE ENGLISH-RUSSIAN AGRICULTURAL DICTIONARY

E. I. SHKONDE

Everyone recognizes the great importance of agrochemistry and soil science to agriculture. Agrochemistry and soil science terms are continually encountered in research papers, textbooks, and monographs on biology, geology, geography, and other related branches of the natural sciences as well as in more strictly agricultural publications.

It is very important to extend scientific cooperation with the countries in which English is spoken and to study foreign achievements and methods. Although many translations of English-language books and articles have been published in the USSR in the last few years, the quality of the translations is sometimes low. Misrepresentation of agrochemistry and soil science terms confuses the specialist reader and does great scientific and practical damage.

The main reason for the existence of bad Russian translations of English soil and agrochemical literature is the lack of an English-Russian dictionary devoted to soil science and agrochemistry and the poor quality of the English-Russian Agricultural Dictionary compiled by B. N. Usovskiy, N. V. Gaminova, and T. A. Krasnosel'skaya (Fizmatgiz, 1952, 1956). The terms on soil science, agrochemistry, and agriculture in the dictionary have been selected without any apparent system and presented to the reader without qualification. It is not known when a new English-Russian agricultural dictionary will be published, nor whether it will be much of an improvement on the existing one. What is certain is that Soviet specialists will continue to use Usovskiy et al for many years to come. It is therefore extremely important that the major mistakes and mistranslations of soil science and agrochemical terms should be pointed out.

Firstly, the very word "pedology" (pochvovedeniye) is given as "pedologiya, burzhuaznoye ucheniye o pochve v otryve ot sel'skokhozyaystvennogo proizvodstva." The term is a synonym for "soil science" and the source of the "definition" is completely obscure. Since genetic soil groups and their classification are confused in the dictionary, the most fantastic names are given to some soils. Thus, "alkali soil" (solonech) is given as solonchak, while "saline soil" (solonchak) is given as solonets. "White alkali" (sodovyy solonets) is translated as solonets and "black alkali" (stolbchatyy solonets) as solonchak, "alkalized soil" (solontsevataya pochva) as solod' or slaboshchelochnaya pochva and "a salt soil" (zasolennaya pochva) as solonksevataya pochva. "Bottom land" should, of course, be poyma, nizina and not "materik" and "calcareous soil" should be karbonatnaya pochva and not mergellstaya pochva.

Krasnozem, zheltozem, krasnaya pochva are given as equivalents for "lateritic soil" (lateritnaya pochva); "primitive soil" (slaborazvitaya, or primitivnaya pochva) is described as tselinnaya or devstvenna pochva, "native soil" (estestvennaya, neokul'turennaya pochva) as "materik", "residual soil" (ostatochnaya pochva) as besstrukturnaya vypakhannaya pochva, "a young soil" (molodaya, slaborazvitaya pochva) as tselina or nov'. In addition "mellow soil" (spelaya pochva) is called staropashka, "compact soil" (slitaya pochva) — svyaznaya pochva, "fine soil" (tyazhelaya po mekhanicheskomu sostavu pochva) — pelitovaya pochva, "sweet soil" (neytral'naya pochva) — nekislaya pochva, "cumulose soil" (itistaya pochva) — fitoplankton and "humus" — chernozem.

It is typical that "texture" (mekhanichoskiy sostav) is defined as tekstura, struktura pochvy, kachnestv. pochvy, raspolozheniye yeye chastey. In the dictionary "clay" (ii) is svalinok, glina and even glinozem, "silt" (pyl') is tina or ii, "loam" (suglinok) is glinozem, sandy clay (peschanaya gliya) is supes; "silt loam" (pylevatyy suglinok) is ilisto-glinistaya pochva, sandy loam (peschanistxy suglinok) is suglinok, and "texture separation" (razdeleniye po mekhanicheskomu sostavu) is mekhanicheskiy raspad tkaney. "Light textured (legkaya po mekhanicheskomy sostavu pochva) soil" is translated as "legkaya po svoemu stroeniyu pochva."

The names of the genetic horizons have been confused. The B (illyuvial'nyy) horizon is given as elyuvial'nyy, the C (materinskaya pochva) horizon as illyavial'nyy and the D (podsilayushchaya gornaya poroda) horizon as pochvoobrazuyushchaya materinskaya poroda. Such a common term as "weathering" (vyvetrivaniye) is called defiyatsiya and eroziya while "deflation" (vyduvaniye, vetrovaya eroziya) is called vyvetrivaniye. "Creeping" (opolzaniye pochvy) is translated as podduvaniye pochvy and "soil washing" (promyuka pochvy) as vymyvaniye.

The English expression for geterogennost' (neodnorodnost') pochvy is "soil heterogeneity" but the dictionary offers pochvennoya raznost'. "Soil covering" (pochvenyy pokrov) is translated as lesnaya podstika "alkalization" (osolntsevaniye) as prevrashcheniye v shcheloch', "rock" (gornaya poroda) as fosforit, "parent material" (materinskaya poroda) as iskhodnaya poroda, "tilth" (fizicheskaya spelost' pochvy) as obrabotka, pakhaniye, struktura pochvy.

In English a soil that is structureless, with all its particles dispersed, is said to have a "single-grain structure", which in the dictionary is odnozernistaya struktura. In the same way the common term "sprinkling" (dozhevaniye) is translated as obryegivaniye, "strip cropping" (polosnoye zemledeliye) as lentochnyy posev, "row crop (proposhnaya kul'tura) as mezhdvryadnaya kul'tura, and "cultivated crop" (vozdelyvaemaya kul'tura) becomes propashnaya kul'tura. "sickness" (utomleniye pochvy) is translated as bolezn', "lime status" (zapasy ivesti) as "pH", and "cropping power" (proizvoditel'nost' i plodoride pochvy) as urozhaynost'. Castor bean (kleshchevina) is given as kastorovyy bob, ritsinus and ritsinnik but not by its true name.

There has been great confusion over the translation of "small grains" (zernovyye kul'tury bez kukuruzy), which the dictionary defines as melkiye zernovyye kul'tury. "Sod crops" (plastoobrazuyushchiye kul'tury) is translated as plastovvye kul'tury.

The symbol "NPK" (polnoye udobreniye) is broken down as "natrium, phosphorus, kali"; apatite (apatitovaya poroda and apatit) is translated as fosfornokislyy kal'stiy "dressing" (razbrasyvaniye ili vneseniye udobreniya) is translated as udobreniye i navoz, and "farmyard manure" (navoz) as komposi i stoylovoye udobreniye. A term such as "fertilizer formula" (soderzhaniye v udobrenii N, P_2O_5 and K_2O v protsentakh is given as formula udobreniy. "Fish scrap" (rybnyy tuk, rybnyye otkhody) is taken to mean "fish guano". "Manurial treatment" (variant udobreniya) is translated as udobritel'naya obrabotka semyan, and fertilizer placement" (razmeshcheniye udobreniya) as mestnoye udobreniye and "silicophosphate" (renaniyfosfat) as iskusstvennoye udobrehiye. Mikroudopreniye, which is the translation of the English "trace nutrient fertilizer" is given in the dictionary for "trace fertilizer". "subplot" (poludelyanko) is given as opytnyy poduchastok.

Pluzhnaya podoshva has an English equivalent "ploughing solew but the dictionary gives "sole shoe". "Subsurface layer" (podpakhotnyy sloy) is translated as podpoverkhnostnyy sloy. "Subsoil" and "underground" (podpochva) are translated as podpochva. For some reason "undercrust" (podkorkovyy sloy) is translated as pakhotnaya podoshva "Furrow drilling" (borozdovoy posev) is given as glubakaya zadelka poseva but "furrow irrigation" is translated as irrigaksiya infil'tratsiey. "Surface water" (verkhovodka) is explained as voda, idvshchaya srerkh l'da, and "friability of soil" (kykhlost' or kroshimost' pochvy) as eroziynost pochvy.

It should be noted that current soil and agrochemical terminology is missing from the dictionary, that the agricultural terms are reduced to the minimum and that the compilers often direct the reader to the scientific and technical level of agriculture in the 1930's.

Every agronomist knows the term "dentrification" (denitrifikatsiya, biologicheskoye vosstanovleniye s poterey motekulyarnogo azota) but the dictionary defines it as prevrashcheniye slozhnykh azotistykh soedineniy v boleye prostyye. The equally common term "chemosynthesis" (khemosintez, sozdaniye organicheskogo veshchestva za schet energii okisleniya mineral'nykh soedineniy) is translated as usvoeniye khimicheskikh sostuvnykh chastey organizmom iz pishchi. "Calcined phosphate" (obesftorennyy fosfat) is given as termofosfat, and "amendment of soil" (uluchshitel' pochvy ili struktor) as udobreniye pochvy.

The compilers of the dictionary and the technical editors have been so cavalier in their treatment of terms that, for example, they give "gleying" instead of "gleization" for ogleyeniye, "conserving" instead of "conservation" for okhrana or zashchita and "veterinary" instead of "veterinary science" for veterinariya. Oprobkoveniye tkaney, is given as oprobkovaniye, oprobkovaniye, borozdovoy as borozdchatyy, wizinnyy as nizmennyy, vskipanoshchiy as vspuchivayushchiy and so on. Their lack of knowledge of the subject has led to bad lexicography. Specialists will be sceptical of such terms and concepts as amfoternaya pochva, Nor can one speak of gumifikatsiya pochvy, but only of gumifikatsiya organicheskikh ostatkov v pochve. Different definitions have been thought up for the synonyms "anabadust" and "anabasinsulphate".

The dictionary instructs the reader that "surface irrigation" (poverkhnostnoye orosheniye) is orosheniye poverkhnostnymi vodami and that "systemic" (sistemnyy specifically) means sistematicheskiy raspolozhennyy poporyadku, otnosyashchiysya ko vsemu organizmu. In the same way "waste" is otkhody, otbrosy and not pustosh' (which is "wasteland"). The dictionary defines "unreclaimed field" (neosvoennoye pole) as par. "Standard aberration" (standartnoye otkloneniye) is given as vyrozhdeniye sorta and "agricultural engineering" (sel'skokhozyavstvennaya tekhnika) as agroteknika.

The serious mistakes incorporated in the dictionary have found their way into translated books and collections of articles. A typical example is Israelson's book on the "Theory and practice of irrigation", published by the Foreign Literature Press in 1956. The same can also be said of several of the translations issued by Sel'khozgiz. It is worthwhile pointing out that the mistakes in the dictionary are also repeated in other subject dictionaries, especially in the English-Russian and Russian-English geological dictionaries compiled by T. A. Sofiano (1957, 1961).

I have not attempted to make a detailed examination of the terminology in the dictionary, but have merely noted the worst mistakes concerning soil science, agrochemistry, and agriculture so as to help Soviet specialists in their translation work and to provide a correct definition of a number of important terms. I hope that this article may help translators and specialists to avoid the mistakes of the dictionary and to derive more benefit from foreign publications on agrochemistry and soil science.

The compilation of an English-Russian subject dictionary calls for a great deal of conscientious and creative work by specialists who know English and have a complete mastery of the present-day state of their subject.

In view of the unsatisfactory nature of the dictionary here reviewed I am sure that the Editorial Board for Scientific and Technical dictionaries will put in hand a large and up-to-date English-Russian agricultural dictionary, in which appropriate space is devoted to soil science and agrochemistry. There is also certainly a need for a definitive English-Russian dictionary of soil science and agrochemistry, which does not at present exist.

CHRONICLE

A CONFERENCE ON HEAT MEASUREMENT IN CRYOLOGY

I. V. SHEYKIN, Scientific Secretary of the Conference Organizing Committee

A conference on heat measurements in cryology convened in Moscow in February 1961 by the V. A. Obruchev Geocryological Institute of the USSR Academy of Sciences to discuss the present methods of studying heat and mass exchange in deep frozen, frozen and thawing soils, snow and ice, and to exchange experience on the construction of instruments and apparatus for research and investigation.

The Conference was attended by representatives of thirty-two bodies concerned with scientific research, planning, investigation, and building from Moscow, Leningrad, Magadan, Vorkuta, Yakutsk, and other towns. Twenty-eight papers and communications on various aspects of study methods and equipment were read at the Conference and discussed.

Particular attention was paid to methods for measuring the temperature of rocks, snow, and ice. A. V. Golubev (Institute of Geocryology, USSR Academy of Sciences) presented a detailed paper on the scope of heat measurements in cryology. Golubev dealt with differences in methodological approach when studying the heat regime of rocks, when determining boundary conditions of heat exchange between rocks and the atmosphere, and when solving particular applied problems concerning heat interaction between buildings and foundations. Particular attention was paid to the possible scope of physical modeling as a method in thermal studies. A paper by Ogil'vi (All-Union Research Institute for Hydrology and Engineering Geology of the USSR Ministry of Geology and Natural Resources) dealt with problems involved in the study of heat exchange in a rock bed with an annual pattern of temperature variation.

Ogil'vi noted the difficulty of studying the processes of energy and mass exchange in this layer and suggested a method for calculating condensation and evaporation at different levels in the layer by analyzing the temperature regime of the rocks.

I. V. Sheykin (Institute of Geocryology, USSR Academy of Sciences) spoke on new developments in the methodology of temperature measurements involving the use of junction-type germanium diodes as electrical temperature probes. This new method eliminates the effect of supply leads for a high temperature coefficient of the diode by a back current of the order of 12%. I. Ye. Dukhin (Institute of Geocryology, USSR Academy of Sciences) obtained a high level of accuracy (of the order of 0.01°C) in remote field temperature measurements using a thermistor instrument of his own construction. Ye. N. Tsykin spoke on the use of thermistors for remote measurements of the temperature of glaciers to within 0.1°C (Institute of Geography, USSR Academy of Sciences).

V. N. Dimo (V. V. Dokuchayev Soil Institute) and V. I. Zhigunov and A. M. Proshin (Gidroproyekt) also spoke on the use of thermistors under field conditions.

All investigators reported and stressed the high stability of thermistor cells which are subjected to preliminary ageing.

L. Ye. Vedernikov (All-Union Scientific Research Institute No. 1) presented a large paper on the productive use of resistance thermometers by the Magadan Council of the National Economy. He demonstrated a highly portable multi-channel remote-operating measuring device based on the M-198 galvanometer and photorecording for measuring temperatures accurate to within 0.1°C. He also demonstrated samples of probes.

A number of communications dealt with improvements in resistance thermometers, thermocouples, and other measuring devices.

I. S. Ivanov (Institute of Geocryology. Siberian Department USSR Academy of Sciences) put forward an interesting new way of constructing a theory of heat transfer. His proposals utilized the methods of statistical physics and probability theory.

M. A. Kaganov and T. I. Kaganova (VASKHNIL Agrophysical Research Institute) dwelt in detail on the results of prolonged research on the development of a method for determining the thermal properties of soil, snow, and ice using an invariable spherical probe. N. V. Serovoy (Chief, Geophysical Observatory) also dealt with the use of a linear probe with a restricted heating time to measure the thermal characteristics of the soil, snow, and ice.

Several communications dealt with the methods and apparatus for determining soil moisture and water transfer in soil.

A. M. Globus (VASKHNIL Agrophysical Research Institute) spoke on laboratory studies of moisture migration.

F. S. Zavel'skiy (VSEGINGEO) and V. D. Ponomarev (Institute of Geocryology, USSR Academy of Sciences) spoke on the use of gamma radiation in direct and indirect measurement of moisture and the study of moisture dynamics. Attempts to use IVP-53 moisture probes to determine moisture potential and the amount of unfrozen water in soil were dealt with respectively by V. N. Chubarov (VSEGINGEO) and I. V. Boyko (Pechora Coal Research Institute).

Two papers were devoted to the measurement of heat flow in soil. Possible errors in the measurement of heat flow by thermoelectric measuring devices were dealt with in a paper by M. A. Kaganov and Yu. L. Rozenshtok (VASKHNIL Agrophysical Research Institute).

L. P. Semenov (Institute of Geocryology, USSR Academy of Sciences) proposed a simplified method for calibrating heat-measuring instruments. V. N. Bogoslovskiy (V. V. Kuybyshev Moscow Institute of Constructional Engineering) spoke on the procedure for measuring absorption of solar radiation by snow in the Antarctic and on the results obtained.

Finally, there were papers on instruments for studying freezing and swelling of soil (G. P. Bredyuk, Transport and Power Institute, Siberian Department, USSR Academy of Sciences; B. V. Utkin, State All-Union Road Research Institute).

As a result of discussion of the papers the Conference was able to note certain achievements in heat measurements in cryology:

1) the introduction of electrical methods of temperature measurement has considerably increased the reliability and accuracy of data in engineering geology, both in prospecting and in controlling the use of installations. Particular progress has been made in the introduction of semi-conductor instruments for temperature measurements under field conditions;

2) multi-channel instruments for temperature measurements in fixed installations and under field conditions have been designed. These instruments record the reading automatically;

3) the new junction-type germanium diode instruments that have been developed for temperature measurement have considerable advantages for remote measurement;

4) thermoelectric measuring instruments are being used to study the processes of heat transfer in various media;

5) probe methods are now being used in research to determine the thermal characteristics of the soil, snow, and ice; and

6) radioactive methods for studying the dynamics of ground moisture have been developed.

The Conference also noted the main weaknesses in the development of methods for heat measurement in cryology and in the design of the apparatus required:

1) the absence of an integrated procedure for physical studies of heat in soils, soil materials, snow, and ice, although such measurements are frequently made for various practical purposes;

2) the failure to organize centralized output of equipment for geocryological research has obliged various organizations to develop and manufacture instruments suitable for their tasks and conditions, since commercial equipment is sometimes unsuitable for geocryological purposes; and

3) there is a lack of coordination between the various organizations in the development of equipment for heat measurements in cryology and this retards the practical introduction of the best prototypes.

The Conference felt obliged to recommend the following measures:

1) That there should be an intensification of research on methods for the joint study of the processes of heat and mass exchange and on the development of the equipment needed.

2) That the experience of the organizations concerned should be embodies in a handbook of heat measurements in soils, soil materials, snow, and ice.

3) That the industrial production of the most satisfactory prototypes should be studied concurrently with the compilation of the handbook.

4) That a work conference should be convened in 1962 with the object of unifying research methods, standardizing equipment and further coordinating work on the heat measurements.

5) That the Conference proceedings should be published as a separate collection.

The resolution adopted by the Conference reflected the present state of the subject and the trends for further work to improve heat measurements in cryology.

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